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Note: Transcript has been edited for clarity, but has not yet been reviewed by the author. Accordingly, inaccuracies may be present. The author-edited version of the transcript will be posted at a later date.

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François Hillion: I will try to explain to you how to – just to put some light on some dark spot in the instrument. And I just select some very specific features coming from the discussions I have had among many of you around the instrument and I just thought we would start with that. And in the second part I will just give you some information about our new developments. So we can ?? these three different items. So I will start from the source spot and then ending in the mass spectrometer (Slide #1). In the source spot I have often questions about how you can get more current or small probe with this part of the instrument. So I will just explain for those who do not use any NanoSIMS instrument how it works in this part we call the primary column (Slide #2). So we have the first part there, which is the chamber, we call the source chamber, where we have both the duoplasmatron and the cesium source. So with these two sources we are able to choose the ion species we will you use for the primary ions – either Cs^+ ions or O^- ions. In addition to the duoplasmatron we have a Wien filter which allows us to select the ion species coming out from the duoplasmatron and mainly what we use is all minus, so we use all minus beam. After that we have here a path where we call the primary column where we have three lens and they are all L1 and L2 and some correctors and some diaphragms. I just want to speak on this part to explain how you can increase the primary current up to several nA of the sample. Because in the common situation when we use the instrument for small probe we currently use a primary ion current which are in the range of pA and of course for some application of, for example, pre-sputtering you need to get more current in the range of nA on the sample. So to achieve this kind of tuning you need to use lens that will de-magnify the source and thus increase the beam current and there is two ways to do that. Either you use L0 alone, which is exactly there, or you use L0 and L1 together. So in this simple graph there you have the probe current in pA and the L0 voltage in volts there and you have two curves (Slide #2). The blue one – I record on a very common instrument – showing that only with L0 you can get some nA on the sample. And the red one here is the simulation one that seems to show that you can get more current in the probe. But here on the NanoSIMS we have a kind of problem. In the short chamber the pressure can be very high, especially when you use a duoplasmatron source – so it can be at least 10^{-5} torr, even $2 \cdot 10^{-5}$ torr. And in the bottom part here we are currently working at $5 \cdot 10^{-9}$ torr, so in between we need to have a differential pumping system and that's exactly what we set (Slide #2). So here in this particular region here we set a small tube which is 2.5 mm in diameter and a small length which allows us to have a very, very large pressure difference in these two chambers. But the drawback is that here you have a kind of beam stop for the primary ion beam. That means that you need to go through this tube; that's one of the first conditions and the other condition, of course, is the demagnification of the beam. So I will explain to you why with LO you cannot get more than something like a 3 or 2 or 3 nA with this condition in the instrument; that's a limitation we have on the NanoSIMS. You compare to a 4F where you can get 200 nA from the sample without a problem. That will remain unchanged on the NanoSIMS. So I just put that there just to show that this blue curve has been obtained with these conditions. FC_p is a Faraday cup we have in the primary column and it's a way to measure the brightness of the source, of the way we use the source; so 33 nA, the source is not very, very (hot) but it's worse but you can increase up to (100 nA) without problem; 33 nA is a common situation for that (Slide #3). So that's another situation where instead of using LO I use L0 another one. So sorry for something – I use volt and bits at the same time; I'm sorry for that; so 1800 is in bits, that is in volts. So the conversion coefficient is 2.5, it's not so difficult but in the NanoSIMS we always, or very often, we speak in bits. So that's the three different curves have been obtained with three different L0 and by changing L1. So that's three different ways to get more current on

the sample and of course it has happened for three different demagnification of the primary ion source so that shows you that there is no absolute value, absolute recommendation. When you want to have more current in your probe you can use L0, a different value, and you can use L1, a different value. Just here again I just show you the difference between an experimental curve and the one that's coming from the simulation showing that there is a difference but coming again from this –

FH: You can have or you can get at the beams of the sample like 30 nA with a FC_p of 50 nA which is not a huge current and with this D1-1 – there are many, many people here working on the NanoSIMS where you don't have this kind of D1, D1 being the – I must explain for that for those who are not working with the NanoSIMS – D1 is the main diaphragm for the NanoSIMS; it is a aperture diaphragm for the primary ion beam – it is really the diaphragm which is limiting the primary ion probe. So these numbers are even for the larger diaphragm we have now on the NanoSIMS, which is 750 microns; so any question about that?

Unidentified Speaker: (Inaudible.)

FH: Good question. The base (impact) is the range of between 2 and 5 microns – something like that.

Unidentified Speaker: (Inaudible.)

FH: Beam current stability? Oh, it's very, very – for the cesium source we achieve .5 Poisson within 10 minutes. It doesn't matter what the beam current is; it shows that in a small probe or in a large probe. The cesium source is very stable. For the duoplasmatron for the O⁻ beam, it's a little bit less, 2 Poisson for 10 minutes, not so quiet.

Unidentified Speaker: (Inaudible.)

FH: It's difficult to answer something like that without being just in front of the instrument with the problems there, in principle, not. The problem with the scaling system is that you have – everything has been designed to rotate around the center of D1. So when you rotate the beam, so you have the sample there, immersion lens, and D1, which is our main diaphragm. So if you really rotate the primary ion beam around the center of D1, you are able to have this kind of beam, you just rotate that around that, you will have ?? elimination. But when you use such configuration for the primary current, it's not sure that you will have beam so large here, large enough, and you will rotate maybe not around D1 sample. So it could be (100 nm) start to be a large field for the NanoSIMS. But in principle you must find a kind of tuning which is okay for that – 100 microns is not so large. Here I just want to do a small – well mainly what are the problems with the small probe size of the NanoSIMS. So everybody knows there is this kind of relation between the probe size, the gaussian size, and aberration. Probe size – no need to explain that; the gaussian size is what you can expect when you reduce the source on the sample – so you de-magnify the source and if you start from source of 40 microns, for example, for the cesium source and you reduce that by a factor of thousands, you will get a gaussian size of 40 nm and that's exactly what we think about that. An aberration can be on this kind of instrument and on many instruments, the main aberration is aperture aberration, which is written like that (Slide #4). The second one is chromatic aberration, which is not so huge for cesium, but

can be relative important for duoplasmatron, so α being the half aperture of the sample, and $\Delta E/E$ is relative energy spread in the primary ion beam. I just give you some value on these two coefficients and just if you can compare that to the 4F, because the 4F is a kind of reference in the field of SIMS. For the same definition, in the 4F the Cs coefficient is 1000 mm and the Cc coefficient is 100 mm. You see how different it is from this whole instrument and that explains mainly why we are able to reach very small probe with a current, which is so small on the NanoSIMS because we have reduced a lot these two coefficients, these two main aberration coefficients. That's a main feature of the NanoSIMS on the primary ion beam side. So, again, α is controlled by D1. So this diaphragm, which is there, controls the aperture of the beam, all the aberration in the beam, because this energy spread is not under control. The cesium beam is something which is the range of 1 eV, coming mainly from the power supply itself, not from the emission of cesium ions. That is absolutely not in our control and so here we just can act on Cs, Cc and α . So here I just want to say something, which is relatively important, is that when you want to work with small probe it's not so easy to know what kind of diaphragm you need to use. Of course you can use a very small diaphragm so you will get very small aberrations that will fulfill your problem because you get a small probe but you will lose all the current in the primary ion beam. And of course, on the other way, you cannot increase a diaphragm too much otherwise you will increase the aberration part and you will gain current but you will lose – the probe size will increase – and you will lose resolution. So of course, by doing simulation, it's much more easy to do. But I give you some numbers there; by doing this kind of simulation, trying to find what is the best fitting, what is the best setting for D1, what gives you, for a given current, for given probe size, the maximum current, we find a D1. That means that for a given probe size you will need a given D1 to get maximum current, optimum current, in the probe. Of course, on the NanoSIMS we don't have so much D1 available and we have now five different D1 – 100, 150, 200, 300 microns and so on. So we have to choose in between this what is different to the one which is the best according to you, the probe size you want to reach. So I will give you a kind of summary about those. Any questions? So, of course, when you want to reach a very small probe you need not only to reduce the ?? from D1, which will use that ?? but you need to increase the demagnification of the source and the best way to do that, or the common way to do that – because there is another way – is to use L1 – maybe I can go back to – but everybody knows where is L1, it's in the primary column, just after L0. So with this lens you will be able to – I can draw something – so your source there, L1 is there, and what we are doing is just, we have the source there. To do an image of the source de-magnify by 3, 4 and this image will be used by the rest of the instrument to produce a probe; so that really is a very simple way we use to reduce the probe size. So I give you here some number coming from simulation but I have tested that and it fits very well with its (prime upper value), showing how the demagnification is changing by increasing L1 (Slide #5). And you see here this point, at 5500 volts on L1, you will get exactly the same as L1 will be not there. So never use L1 when you want to do small probe, like 5000, otherwise it will increase or decrease the demagnification, always use L1 above 5500 volts. Of course when you increase the demagnification you will decrease the current in the probe dramatically. You see that at 6500 you have decreased by a factor 5 the probe current and the demagnification has been only increased by a factor of 2.5. So that's very efficient to decrease the current in the probe. I will explain why we currently get something like 2 pA with a probe of 100 nm and only .5 pA at 15 nm when you use the source in the common way. Of course if you heat more the source will get more (current) but you have decrease very rapidly the probe current. That's another question that I often hear about the

NanoSIMS – on the NanoSIMS we have the possibility to change the distance between the sample and the first lens. The first lens we call the immersion lens and this immersion lens is a lens that acts both on the primary and the secondary ion beam and so we have a Z movement and we are able to change the distance, which means the lens in the sample, and the common distance is set to 400 microns – that means that distance between the front plate and the sample has to be – just say set that to 400 microns. And a very common question is what happens if you increase that to 500 microns, for example? If – I will maybe lose lateral resolution or something else so I just give you some information about how it changes with the distance and I just start with a graph – this is the same graph – one is in log and the other one is in linear scale (Slide #6). This graph is showing you how the 2 coefficients, the 2 aberration coefficients, C_c and C_s , change when you change the focal length of the lens and you can see here again why we use a very small focal lens on the NanoSIMS because you can decrease dramatically all these coefficients; for C_c decrease nearly linearly with the focal length but for C_s decrease with the power of 3 of the focal length, so it's very, very efficient, at least what we did on the NanoSIMS. Instead of having a focal length on the 4F I don't know really but it's around 30 or 40 mm the last probe forming length of the focal length of 30 or 40 mm. Here, the focal length of the last lens of the primary ions is around 6 mm, so it's very small. So that it is exactly the same, log, log, scale; you can have ?? this coefficients there. So when we change the distance between the lens and the sample by 100 microns, for example, which is relatively easy to have when you change the sample, when you move a little bit your sample back. What will be the effect? So in fact as the demagnification of this last lens is very huge changing Z is exactly the same as changing the focal length as we are using here an object which is very far from the lens, directly change the focal length. And what you will only with 100 microns you will get a change in the demagnification of only 1.3%, which is nothing, absolutely nothing. So concerning the gaussian size it will not change so much – one percent is amenable to see that. And so, aberration – what will happen? Of course, if you send the sample a little bit away from the lens, the angle at the sample will decrease and this decrease will be roughly proportional to $1/f$ for focal length and as all that is proportional to the power of 3 of the focal length and that aberration the power of 3 of alpha, it will not change. And for the chromatic aberration it will be the same as the geometric aberration are proportional to alpha, it will not change at all. In fact you can use the instrument with a Z , which is 400 microns or 500 microns, it will not change anything on the lateral resolution, it will not change anything. If you don't take care about the secondary ion beam, which is another story, you can use the instrument, if you are doing images, for example, just imaging carbon and oxygen on the sample without doing any high mass resolution don't take care about that – you can really use the instrument as you want for that. No questions? So I just do a very small summary of what you must have in mind when you use instruments for a small probe (Slide #7). With $L1 = 0$ just without using any lens in the primary current; just use this kind of diaphragm – D1-2 or D1-3 – and you will get probe size in the range of 100 – 120 nm. I just give you the size of D1 there, which is 300 – 200 – 250 – 100, and with the new D1, which is not available on all instruments, but can be changed, there is an additional one but the ones we use for the small probe are the same. So and here I'll give you some practical rules but you can change that if you want. Any questions?

Claude Lechene: François, particularly do you use a lot of L1 or not when you are working?

FH: Depends – it's a tradeoff between primary current in the probe and demagnification.

It depends what you are really doing there. It can be – I don't know if I answer your question – if you want to go down to 15 nm you must use L1, there is no doubt about that but as we have a cesium source which is limited to brightness of 100 or between 50 and 100 you cannot expect to detect ppm – I explained to you that this morning. With a 15 nm probe you cannot expect to detect 10 ppm in any ??

CL: No, but what I meant is more practically if one analyzed 50 microns by 50 microns field and you want to reduce your time of counting why not always use L1, basically?

FH: To increase the probe current, it's not to decrease – yes, why not? It's a question of resolution. First you have to determine what kind of lateral resolution you need. After that, okay, if you think that 200 microns is enough at 200 nm for example is enough to do your job so do it but I don't understand –

CL: I think we'll talk about it tomorrow.

FH: Yes, it's a question of better resolution. You have to choose that first. After that you can use L1 or not but it's not –

CL: Personally I like always all field being the same to increase my resolution and I mean at same diaphragm and the count rate so to use L1 – but we'll talk tomorrow on what you said.

Unidentified Speaker: (Inaudible question.)

FH: I can do what you want.

Unidentified Speaker: (Inaudible question.)

FH: No, oxygen is the same, absolutely the same. Yes. Except that the probe size you will get are much higher, but that's all. But it is the same – maybe I can go back – I will come back to that. I just pick from the cesium because it is the way I do the job but of course we you use the duoplasmatron you use the duoplasmatron, the Wien filter and then you have lens here, which is a lens you need to use when you use the Wien filter and the diaphragms there is there to be your exit diaphragm with the small mass spectrometer which is the Wien filter and the source in this case for the duoplasmatron will be D0, diaphragm D0; so you can exactly use the (parameter) the same way I explain that except that the beam position, the source position, is a little bit different so you will not get exactly the same lens setting but it will be the same story, can use the same principle.

Georges Slodzian: (Inaudible.)

FH: I will explain that – the duoplasmatron source there, the Wien filter is there, this lens L0, and of course, according to the mass, you have, for example, all minus here, all minus here, and you use the diaphragm D0 to select the beam and this point will be used by the rest of the column as the source. If I set the cesium source, the cesium source is around there or there, so it's not so much different; it's different for sure. We use that, so Georges says that D0 will be the source size, in a certain way, yes. When you use large D0 the source size is given by the

shape of the beam there; but when you use a small DO which is absolutely necessary to go down to small probe size finally what you will use as a source is the diaphragm size itself when you use here something like 50 microns; it's very small compared to the size of the beam which is more or less something like 200 microns so you will really use that as a source. The source size will be the diaphragm size.

GS: (Inaudible.)

FH: Yes, it increases the relative brightness, too, if you just take the central part of the beam so it looks like it is more bright but the probe it's decreasing; it's more bright but it's decreasing. And you can use exactly the same rules except that the value will be different because the source position is a little bit different.

GS: (Inaudible.)

FH: No, it's directly connected to the physical property of the source. The cesium source is – for the cesium source to work like that you have an ionizer there, you have something like that, you have cesium, not all cesium coming there, but ionized on the hot tungsten pellet which is there, and all ions are escaping like that. We'll find again the crossover from this morning. And here you have something at the exit of the cesium source, which is a crossover, and the size of this crossover, according to what we use, the kind of opening we use there and so on, is between 40 and 50 microns; that's one property – you need to know what current will be in the probe. Next one is the brightness, the brightness of the cesium source is between 50 and 100, something like that, and the final parameter is relative energy spread, which is – must be very small because it's a sample ionization which is – we get something in the range of .1 eV or something like that. But due to the power supply we use and so on, so you will get something like 1 eV. If I compare to the duoplasmatron, which is a plasma source, on this plasma source, what we use we use the area of the plasma, I don't want to speak about that, but here we use a 500 microns aperture and here you have an electrode which accelerates the beam there and finally what you get there is a source size of 250 microns, a brightness of 10, and that is 10 eV, 10 to 15 eV. I will explain why we are absolutely not able to go down, to get very small probe size. With a useful current with something which is useful to analyze of course you can go down to 25 nm as we do for the cesium source but with no current, and because just after we use all the effect of aberration which are there. So for the cesium we achieve something like a maximum or optimum or best value we never achieve is 25 nm but we currently work at 15 nm without problem. This source 300 nm is something we can do without too much problem and the best we achieve is 150; between 100 and 150, something like that.

Unidentified Speaker: (Inaudible.)

FH: It's 2 pA; here it's, I don't know, it's .5 pA, something like that – between .5 and .3, something like that. After that you are quite unable to see something.

Unidentified Speaker: (Inaudible.)

FH: Cesium – between .5 and .7 and that is .30, something like that. But with this kind of probe, again, George explained that this morning. We are just able to analyze or to image mature elements. That's it. There is not enough current in the probe to have something bright

enough. In certain case if you are looking, for example, with the cesium, with this kind of cesium probe to oxygen, you can go down to 1%, maybe, something like that, concentration of 1%.

Unidentified Speaker: (Inaudible.)

FH: I was too fast. Those are two main aberration coefficients – so Cs, which is in charge of aperture aberration, and Cc, which is connected to chromatic aberration, and the way they change with the focal lens. It's equivalent to Z in the case of E0. What we have EOP there and when you look at how it works in the final part of the instrument, you have the sample there, which is very near from the lens, and here we use an object which is coming from the rest of the current, which is very far from that. That means that the magnification there, G, is maybe 1 over 50 or something like that, I don't remember exactly the number, but it's in this kind of things. That means that here you have the focalization point is quite the focal point. That's a very basic thing. So that means that when you change the sample position, you will change the focalization point, that means you will change the focal length, exactly by the same amount. Because the focal point, if I do a large amount of that, it's like that you have the surface here and the focal point is just above the surface, not very far, so when you move that everything is attached to that. And here you can see how fast it is we see – Cs is going down over 3 of the focal lengths.

GS: (Inaudible.)

FH: Maybe I can give you some numbers. When you will do that, maybe I must take care about people who did not use the NanoSIMS; so I'm just speaking about the immersion lens, we call E0 and in this immersion lens we have many electrodes, part of them are acting on the primary ion beam, and others are acting on the secondary ion beam. So here I just forget what is going on with secondary ion beam for the moment. So I just speak about 1 electron in E0, which is call EOP, p like primary – not so difficult; and this one is in charge of focalization of the primary ion beam. So when you will move the sample by 100 micron, for example in this direction, you will have to decrease P by 60 volts; ΔEOP is 60 volts – that's something which is a common energy we use for the primary.

Unidentified Speaker: (Inaudible.)

FH: No, exactly the same – log, log, scale; so in log, log, scale you are adjustable to the time and the coefficient of the – yes, exactly the same graph but just log, log. But with log, log you are lost – you see these numbers which are more sensitive to your mind; instead of 4, it's much more difficult. Yes, nothing else.

Unidentified Speaker: You may get interference. Do you get interference with the secondary beam going up?

FH: No. No, there is no collision. If there is collision – there is no collision, nobody can say that. But the level of collision is very, very small. I don't know, Georges, if you know something about that.

GS: As far as I know no evidence could be found that that's an effect. But in principle you may have a cross section co-collisions – it's slow, but some may occur but it's a marginal

effect. The point I was making this morning, which is related to your question, I would be more worried about the space charge because this changes the potentials a little bit and since the secondary ions are emitted with low energies it may change a little bit the trajectories but again it may also be a marginal effect.

CL: One of the things I am totally confused. Practically also when you change your Z for sure you will change your secondary ions so it can – in other words when you say it has no effect, for sure it changes all your secondary ion (at tuning).

FH: Yes, but I just say that just very precisely. I just speak about primary ions. That means that if you don't take care about certain – I will explain to you what happens when it changes, of course, for the secondary – it's a bit change and you have to take care about that but it's not always the case because very often you just don't do only nitrogen isotopes; sometimes you just look at your sample – very basic work, Bill is doing images without any ?? in the sample – you just do it. But, of course, your right – on the secondary ion part it will change a lot. It's absolutely forbidden to do that – work with ΔZ – (100 microns) will be crazy, for sure. So I just want to speak a little bit about – oh, yes, I forgot something – all this marvelous (chemistry) come from Frank and not from me; it's very useful to have that and it's very well done. Thank you for that. So I will speak a little bit more about this part of the instrument. So the primary column was there and after that all the primary ions are sent to this part of the instrument which is what we call the co-axial column where we have both primary ions coming to the sample, secondary ions coming from the sample, primary electrons going to the sample, and secondary electrons, when they are detectable, coming out from the sample. So this part is a little bit intricate. So you this immersion lens there with these three electrodes. S in charge of secondary, P in charge of primary, and this last electrode which is connected to the sample and we call W for Wenhelt it acts like the Wenhelt for secondary ions. I don't want to explain – if you need some explanation about that, ask me – but I don't want to re-enter that because there is many people that know that the part but I can explain to you how it works in the case about in this region. But I just want to focus my talk on the dynamic transfer and the way we can tune it and why it's not easy or so easy to work with that . So the primary ions is scanned with three pair of primary plates which are B1, B2, and B3, and unfortunately, or fortunately, these three act both in primary and secondary because it is in the common way – the common optical part of the instrument where you have plus ions (Slide #8). So the best way to imagine how it works is to start with secondary ions. As Georges explained to you this morning, when you move the secondary ion beam emission point on the sample, the secondary ion beam at the exit – there's a crossover at the exit of the immersion lens – will move, the secondary ion will change it's position; so this comes from simulation, not experimental things, that give you the way the secondary ion beam is moving when you scan the beam along the sample. So that here I just do seven positions corresponding to -30 microns, -20 and so on, on the sample, so spot on the sample and they're always on (third plane) and what is there is two things – the younger of the secondary beam at the crossover – so I will draw on the board there – it will be easier to understand – exactly the same as this morning – so we have the sample here, some up-taking between, which is mainly E0, this plate is called B3, and we get at the crossover is in the center of these three. That means that, of course, when the beam is straight, it starts on the axis of the sample, you will get a secondary ion beam like that. When you are here, let's say we get something like that; and when you are here, you will get something like that. Exactly what you can see on the graph there that means that the angle is just starting from negative value to

positive value there. And of course, in addition, if you look at what is going on the entrance slit, which is there – entrance plane there – I can do a small O because very often we have an aperture there, so you will see the beam moving there, too. You will see this kind of movement, which is a lot. That means that you will lose all the beam if you don't have something to compensate that. Of course, we use B3 to compensate the beam so after we pull these three, of course, all these three beams are sent ?? on the axis of the mass spectrometer – exactly what we do with B3. So I will come back to that. So that's the first condition we need, so we just need to pull up B3 to have immersion lens beam in front of the mass spectrometer. And then, just by imagination, you just have to set B1 and B2 to send the primary ion beam where the secondary ions come from. So I will give you some numbers just to – if you speak about this point, which is +30 microns, so if you need 10 volts you have to bend the beam so it's going to 30 microns on the axis. Now with the two other plates, which are B2 and B1, you need to find a condition, of course it will act also there, you will find condition on B1 and B2 to send the primary ion beam like that to reach finally 30 microns. The way we do the simulation ?? the right settings on B1, B2, and B3 otherwise it's absolutely you never find any other way to explain that. It's the way we do the simulation so it's a way we can explain things and it's the way it works, of course.

GS: The only point which maybe is difficult to understand is you didn't account for P1 in your drawing.

FH: Yes, I didn't account for P1, because P1 is stable. There is no scanning action on P1 so you can just forget it; I can explain that if you want but here I just drew a straight line but – I'm not happy with your question. Don't do that again.

GS: You make me confused because P1 is not on your drawing.

FH: Yes, I agree with you. I will do the job completely, but it's more difficult to draw. But I will do it. B3 there and B1 and B2 like that and we have to rotate around the center of B1 so I just prefer to do that like that. That's it. So that means for the primary ion, of course here, you have P4 and here you have P1. So the primary ions, you just start to bend the beam a little bit in B1. There around the center of B2, it is bent, so you will enter in D1 like that in the final region sample. It doesn't help you to do that because you can forget all these deviations, which are 6 degrees deviation, which are absolutely stable. It doesn't participate in any sense to the scanning – it's more easy to explain and do a straight line; it doesn't change anything. For the primary ion beam and for the secondary ion beam, it's something like that – a straight line with only B3. This is much easier to understand.

Unidentified Speaker: How precisely do you control that?

FH: I will explain to you. So it works like that; so now, how to tune that. Which is a little bit – so first you will start with value coming from the simulation for B3 and B1 because what I decided to, not to be too much confused, is to set these three in B1, theoretical value coming from the simulation and just act on B2 as a free parameter to tune the whole system (Slide #9). That means with B3 and B1 you are not too far from the right value and you just use B2 which can be tuned indefinitely in x and y; x being the vertical plane and y the horizontal plane because we need that as we have this kind of deviation of the beam in P1 and P4. You have a kind of (astigmatism) in the scanning system so in x and y you don't have exactly the

same –

FH: We'll test the motion of the secondary ion beam – the only point we can tune. So we'll just try to stop the secondary ion beam moving when you scan; so if your B3, for example, is not well tuned, when you will scan the beam you will have a slight movement. Of course, instead of having for 60 micron field something like 300 microns, you will get something like maybe 20 microns, which will be very small, but as here you are able to use an entrance slit which is as small as 10 microns you will lose completely this beam; so that means that when you will – but if you use a small slit, let's say 10 microns by 10 micron waves and 100 microns height you will have something like that, for example. So all that will be bright and that will be dark just because when you scan the beam there the secondary beam goes away from the slits there. So it's exactly what you need to do when you tune the system, just scan the beam on a surface you think is emerging, (so take a second away for whatever it is), implant that with cesium to get a very homogenous signal on the whole surface and just set a slit, a small slit, and try to tune that with B2 to increase the part which is completely bright. That means to reduce the beam movement at the entrance slit. It works very, very fine with this kind of – you will see the bright part increasing and after decreasing if you increase B2 from even values. Of course, you will find the best B2 will be when you reach something completely emerging, as emerging as possible, because, of course, you cannot expect to have something absolutely flat everywhere due to the fact that the scanning system is a linear scanning system; so we have something which is absolutely linear with a (film), which is not the case. Of course, you have (second order) effect on the plates; that means that when you power the plate from 5 volts to 10 volts, you don't double really the scanning area; there is some second order effects which are not taken account in our system.

CL: François, which slit are you talking about?

FH: Entrance slit.

Unidentified Speaker: (Inaudible.)

FH: No effect. So first you do that. Imagine that you have your B2 and B3 and B1; B1 and B2 haven't been changed but you have found your B2x and B2y and then just what you have to check is finally what kind of field you are scanning because by changing B2 you change the area you scan; so instead of scanning 30 microns maybe now it's 29. You just have to measure that on a silicon grid or something which is a grid or give you the real field you scan and you just solve that in the software somewhere, in the setup, saying that now with these kinds of settings for that kind of setting you will scan 29 microns or something like that. That's all.

Unidentified Speaker: (Inaudible.)

FH: Yes, that is why we don't touch B3, because B3 is –

Unidentified Speaker: Not at all? At no stage?

FH: No, I give you here some number – that comes from simulation. When you do the

job you find something which is this theoretical value for B3 and B1 and this theoretical value for B2. And on a real instrument you get something not very far from that, except that very far doesn't mean anything because not very far – that means that we'll change to maybe 4000 or 2000 because B2 is a plate which is not very efficient on the beam. So even if the coefficient changes by 50% it doesn't mean that it changes a lot, so it's not a very efficient plate for B2.

Unidentified Speaker: (Inaudible.)

FH: No, the noise is very low. We have very, very low noise amplifier on this part of the system. This is why we have – that's a good question. So we have two kinds of electronics – we have a first electronic which goes from 0 to 45 microns, something like that, and after that we use another electronic volt, so we have on this, on small fields, lower than 45 micron, we use very low noise per amplifier but they are of course limited in voltage range; we can not use that for very large field. So at this kind of field, around 50 micron, we switch and we use another (volt), the factor is 10 between the two volts, but it can be a change. I just write there saying that of course you have to calibrate this change but it's very often only 10, you have in the separate set up a way to change that, but it's not a real problem.

Unidentified Speaker: (Inaudible.)

FH: No, in everything. If you look at –

Unidentified Speaker: (Inaudible.)

FH: When I speak about that, it's just when you look at – that's a perfect scanning system – so when you want to go there I go there. But on the NanoSIMS I don't want to draw something which is not true but it's something like that; it's roughly – we have distortion on the bottom like that and also like that – of course in the center, in the center part it's okay, but on the side you have (non-linearating) plates – it means that you want to go at 30, 30 and you will not reach 30, 30 but you will reach 29.5 and 29.8 – that's the case.

Unidentified Speaker: So is that non-linearity fixed for all fields of view?

FH: It's not fixed at all. They are –

Unidentified Speaker: It occurs in all fields of view?

FH: Of course, but here it's very, very low.

Unidentified Speaker: In the center.

FH: What you cannot do with that is just put your image in the center, it will not fit, but nothing else; if you find a small grain there and another one here – it's true. It's just you cannot fit all your image to the sample because we have distortion.

Unidentified Speaker: Distortion and if you needed to calculate critical dimensions you should be very careful about that.

FH: No, because if you use the NanoSIMS to determine distance between two grains and if you need to have very high precision you will use a very small field.

Unidentified Speaker: That was my question. Thanks.

GS: I would just like to add a small comment about the distortion here. As François very well said, if you wish to take an image and put it on the original sample, there will be a mismatch, a small mismatch; but if you take two different elements, there is no mismatch at all.

FH: It works, in fact. So maybe I can do a small comment about something else coming from this morning; so we were speaking about crossover and position of crossover and so on – on the NanoSIMS in the entrance slit here we don't have the crossover as it is on the 4F or another instrument. I will draw that there. So it's like that – you have the entrance slit there, and the crossover is there or the image of the crossover because we start with a crossover very near from the sample, we do an image of this crossover in B3 like that and here we have another image. And why do we do that on the NanoSIMS? It was not planned to do that. Just we found that when we tuned the NanoSIMS for the first time and I just say it's a pity to put the crossover there, we lose a lot of transmission and it's not so good, so we set here a kind of beam waist, something here which is a beam waist, but the crossover is at the back. Of course it will be much more easy to tune everything if the crossover will be there because there is no movement. Of course as everything is rotating on crossover, around the crossover, if you put the crossover there, there will be no movement in your entrance slit; absolutely no movement. Of course you will have to do something here. While you have the aperture slit, you need to have roughly a motionless beam. But even if you have a very, very small movement, it will not affect the secondary ion beam in the same way as now, where you have a small movement, you just move that very rapidly. And why do we use that? It's a question of transmission, but not only. As we use the beam waist there – even without it we have a mass resolving power which is very small because the crossover is something larger in the immersion – much bigger than the beam wave there. So there are two advantages. Transmission, which is higher, but also mass resolving power because we start from a point, which is already something small. Of course we have a drawback, which is the fact that when the beam moves for a different reason, and it can move for many reasons, you will have a larger effect on the secondary ion beam. And it's also why we don't give up to put the crossover in the entrance slit in the center – just to try to see –

GS: I will make another comment here. Even with this waist we can make the beam completely still when the beam is, when you ?? the beam, but maybe there is one adjustment that should be added because if you have two parameters you can make the beam fixed in one position and the angle also canceled. And if you cancel, if you make one position of the beam still, and the angle still, also, then it won't move at all. But I don't know, I have not worked precisely on that problem. It may be one of the plates – there are so many plates on your thing – that if you add a little voltage and if it means to make this, this, well from seeing from very far, maybe, it could be fixed.

Unidentified Speaker: All the slit is constant or you can change?

FH: No, what we have here is transfer optics in between the immersion lens and the slit. And mainly, not mainly, it's only, we have two slit lens – so I can draw that like that – what we

call LF2 and LF3 – and slit lens is just a lens that only acts in one plate. It's not a round lens, it's two times ?? at high voltage so you can have focalization only on one plate. And this is what we do here – maybe I need to do something more clear otherwise it will be more difficult. If I do that here, you have the entrance slit there, and what we are doing is something like that. You really focalize the secondary ion – the secondary ion beam there in the entrance slit. I mean LF3; ?? is the third plane; that's in the plane where you have the magnet and so on. In the other plane what we have there – another sketch – we have again that and of course the entrance slit is much larger than the vertical plates. Height is roughly something like 10 times the width there. We have another lens there equal LF2 and this lens is more or less control the height of the beam so we don't focalize the beam in the entrance slit. We leave it. Here we have for the beam a kind of slit shape. And that setting – it's fixed. Don't change it. I will explain that. We set that at the factory and you don't change it. It's a very important feature of the instrument that we have a slit shape to control. I will explain that after some aberration we have there and so.

Unidentified Speaker: LF2, right?

FH: LF2 and LF3. You have LF2 there and LF3 in front of the entrance slit. And when I speak about the crossover, of course, it's a crossover always on the plane is somewhere there but here it's more difficult because as we don't do anything the crossover is sent more far away from the entrance slit. Because it's a non-stigmatic – starting from there, it's a beam which is a direct image, if it still exists there, disappears after that because it's non-stigmatic optics does that. So now when you did this job to tune them and limit transfer and you are very happy and a change of sample or you change your position of the sample and so on and not everything disappears but it changes. So the tuning of this dynamic transfer change and in fact it's very sensitive to the emission point or to the distance between the sample and the immersion lens. So I just – that's very funny – I don't know what that –

GS: And of course the fonts –

FH: Yes, the fonts are not the same. So that is E0S now we are speaking about the secondary – zero means an immersion lens and S, for the secondary. I need to explain that other it will be much more difficult to understand. So you have the sample again there and the immersion lens is in front of the sample and here I speak about E0S which is an (angle) inside the immersion lens which acts only on secondary. Of course, the primary electrode is there but I don't speak about that. And here you have B3. So what happened is when you change the sample position, or when you change the settings of this (length) which is the same effect, it has the same effect, it will move B3, the crossover in B3, and it will also change, if you are speaking about 30 microns which is the case there, it will also change the exit angle in B3. You see that on this drawing; so when you change B3, E0S, sorry, for B3 you get 10 volts, corresponding to 30 microns, that means that here for 7000 on S, 10 volts on B3 and 30 microns – this an alpha scanning field – everything is okay for the dynamic transfer. So we have 0 – you are perfectly tuned for the dynamic transfer. Now we will change only ?? by 100 volts which is not a lot. And what happened is the position of the crossover moved, it moves by .8 mm, it's not nothing, and the angle corresponding to 30 microns changes, too. That's a big effect on the secondary ion beam. So knowing that the only way to do something very stable with the secondary ion beam or to try to do it is to keep E0S constant (Slide #10). That means that you have to keep the sample position as constant as possible with respect to the immersion lens. That's a consequence

of this dynamic transfer – you need to tune, you need to have the right settings. And so the only way to do that is to keep the S constant.

Unidentified Speaker: How about if you change this FS here in between the lens? Can you change that because that will affect crossover?

FH: Yes, but it's not – everything is attached. Here the position of the beam waist in the entrance slit is attached to S. So that means that when you move the sample back you need to decrease S to have the beam waist in the slit and you will move the crossover in this way. So everything is attached – the position of the crossover and the position of the beam waves and the entrance slit. So you are stuck. You need to have the same EOS.

GS: Well can we go back to the beautiful drawing that you have made on the assembly – there is P3, well I still think that if we had put a voltage, an additional voltage, on – we have one parameter more and we are not so constrained by the crossover problem because at that time whatever point around which you rotate you change also the rotation angle so that it is zero. With two parameters you can have a straight line. It should be possible. I didn't try but maybe François one day will be convinced and do it.

FH: No it is true if it is one particle or more. You add one parameter. But true is this condition of staying on the same S –

GS: I want to also to make another comment. I understand very well, François, when you say I put those lens, I don't want to touch them, and those one I don't touch them very much because you see there are many systems in this. If, for instance, you wish to go on your own and say – well, I understand everything and you start moving this. You can spend months on the problem and finally it's just like with the computer when you have a beautiful image, you know with the image processors, and you say, well I will make a better picture and you try to change the contrast, brightness, and so on, and finally you go back to your computer settings –

FH: Yes, I agree with that. What I try to do is give some general rules to anybody and saying – okay, do that; don't do that; and I prefer you tune that instead of tuning – because as you see we never speak about that before exists – attack from the secondary ion, after than you will be lost. What is your job, is doing samples, not doing instruments, so you just have to have basic rules for using some the best way but not trying to tune everything.

HV: When I learned electron microscopy I worked with Siemens where we had to adjust everything – all the lens were manual, everything was just moving around – now you push on a button, everything goes – do you think that's going to happen here?

FH: I don't know. I'm not the right guy to say that because I know how it works, I know how to tune it very rapidly, but I think that if you know what you expect from the instrument, if you know what you want to do with your sample, it can be relatively fast to tune. Of course if you want to tune everything, because you want everything – you want to do 15 nm probe with high mass resolving power because you are doing oxygen isotopes on grains, insulating grains, and so on and so forth – you can not expect to start on Monday and work on Monday afternoon. You need time because it's very difficult and so. But if you want to do a relatively – not basic sample – but something you need images and so on starting step by step it's really not difficult.

But, of course, it's not a simple instrument, it's not an SEM – you have to do it.

CL: Maybe tomorrow afternoon you could tell us what is the last dogma – not dogma – let's say last recipe to tune because I just heard something which is new to me which is don't touch E0S, touch B2.

FH: No, I didn't say that. What I said is according to the fact that the dynamic transfer is sensitive to B3, if you want to stay in the same conditions in those dynamic transfer electric transfer, don't change S – and it's also true for the mass spectrometer. If you want to stay in the same condition for the secondary ion beam cutting you will do with the slits, don't touch the E0S, stay with the sample at the same position, exactly the same – Z's and S's are really connected.

CL: Except that practically when we change field even, we always change a little E0S when we are in isotopic ratios – why?

FH: Again, it depends what are you doing. Changing S by 20 volts, it's not a big deal; it will not change everything. It's just a question of – you know that – you are too old to not know that. It depends what you are doing.

Unidentified Speaker: Experienced.

FH: Right. We will stay in this same region because it's again something which I have a lot of question about that – about all this P1, P2 – not P1 – P1, P2 and Cy (Slide #11). So here with the LF2 and LF3 we control the shape of the beam, so we focalize with the beam, and then after that we send the beam in the mass spectrometer because the mass spectrometer really starts at the entrance slit. So after that we have a corrector C2 which is used to re-center the beam aperture slit, the hexapole, the electrostatic sector and the rest of the mass spectrometer. So here the dogma has changed, according to Claude, has changed maybe from six months ago or something like that, saying that I would prefer to stay with the mass spectrometer, which is always the same configuration. That means that you know your slit position, your entrance slit, aperture slit and so on and you stay in this position. So you can expect that your mass spectrometer condition will not change. Because you have exactly the same settings for all lens, for all optical elements and you set your slit at the same position. So you have your settings for the mass spectrometer. And then I prefer, we found with Frank, for example, by doing some experiments on the instruments, that the best way is to re-center the secondary ion beam by using Cy and P2 and P3. So Cy on the third plane, you just use Cy to re-center the beam in front, just in the slit, and P2 and P3 to re-center the beam in the vertical plane. We just change three optical elements to change the beam position in front of the mass spectrometer and the beam, staying at the same place, by the action of B1, B2, and B3. Not a problem, we just speak about the secondary ion beam position. So exactly what I just mentioned. So for that you have software to do that. You have software we call secondary ion beam centering where it does the job for you, checking the position – horizontal plane, vertical plane – and then finding the optimum value and setting that for you on the instrument. Just there I will just mention something because it's very sensitive. In order to change the beam position in the vertical plane, here my drawing is in the vertical plane, there is the entrance slit there – there's the vertical plane – that's P2, P3. Here to re-center the beam in this plane we need to re-center, to move the beam, to check the beam

position, but to move the beam parallel to the axis, otherwise we will have different angle for them, for the beam is not correct. So when we will check the position of the beam, we will move it, and for that of course we need to know and we need to set that – what is a relative ratio P2 over P3 or P2 over P3 – that means that when you change here by 2 volts to maintain the beam, when you change that, you have the beam parallel to the axis, you need to change P3 by 1.3, for example. And that is very sensitive to the value of LF2 and exactly what I just show you on this graph (Slide #12). The ratio is P3 over P2, when you change LF2 in bits and on quite all instruments LF2 is set to 1250, but it depends from the story of the instrument, sometimes it's 1200 or 1210, or something like that; so take care of that. The standard value is .36, but it could change a lot with LF2. And it has an action of the way the mass spectrometer will work after because you will not only change – we set the position of the beam in the slit but with another angle so it will be directed for the mass spectrometer and change the mass spectrometer resonating power. So just be aware of that.

Unidentified Speaker: P1 and P3 should have the same value in theory, right?

FH: No, it has been designed like that but it has just been designed like that to – because at the very beginning what we were thinking that we were able to decrease the number of power supply we need to tune the instrument as well as for example E0S and E4 are very, very close in value but finally we use two power supply and for P1 and P3 we use two power supply so it doesn't matter if P1 and P3 are different.

Unidentified Speaker: But in order to be a chromatic?

FH: No. It's not – yes, yes, okay. I can give you some words about that. It's true that here we have – for the secondary – we have P1, P2, and P3 and all these deviations – so the whole deviation is a chromatic and it has to be because the secondary ion beam is an energy spread. Of course here, when you look at what is going on in P1 you have high energy secondary ion which are like that and here low energy and in P2 and so on and finally at the end come out all are exactly the same as it was before. So it's just a chromatic deviation and it's true that for it to work like that it has to be the same angle, it has to be, for example, here we have 6 degrees, 12 degrees, and 6 degrees, again, and it's true that it has to be the exactly the same; but here we change P3 by a very, very small amount so it is the case.

Unidentified Speaker: I guess what I was going to ask was how much can we change P3 before we have to start worrying about this?

FH: Too much to be useful. It will escape from this (heat) for sure. And don't forget in that this direction we don't need to have mass resolving power, it's a vertical plane. So here we just have to control aberration because we have to control that the height of the beam of the way we send the beam in the mass spectrometer is not too bad concerning aberration but it's not – even if there is a slight energy dispersion in the vertical plane, it wouldn't effect the mass resolving power.

Unidentified Speaker: (Inaudible.)

FH: This one? Simulation. But you can do it by hand if you want. Just take a small, a very small ES5 and try to do a change of P – P2 and P3 are relatively large, let's say, 10 volts

and try to find the right settings to have – I can explain that, but it's not so difficult to do. But the best way to follow that – so you have in the set up somewhere in the tuning section you have this coefficient. You have that to check. No other questions? So I just want to speak about this mass spectrometer (Slide #13). I just give you some general formula but it's absolutely not useful to know that. Just to write something which is not completely crazy. So the mass resolving power which is inverse of mass resolving power is of course connected to the widths of slits so that the demagnification you have in the mass spectrometer – the demagnification of the mass spectrometer is given by the optical property of the mass spectrometer and its value is just for information. For example, reduce 350 mm the magnification is .6 – that's the width of the slit, of course, and again, the width of the slit has to be set there when the slit is small. Of course, when the slit is large, as in the entrance slit we have beam waist, that the beam waist emission will be set there. It means that here, according to what we have on the NanoSIMS, you never increase that above 30 microns, 30 –35 microns. That's the size of the beam waist; and after that you have the aberration part – I just want to speak about that. So you have two main aberrations on the NanoSIMS – so they are aperture aberration, which are second order aperture aberration, and chromatic aberration. So this second order aberrations are related to three parameters; so the example which is there to compensate the effect of this (order) to suppress the second order aperture aberration. The aperture slit which controls the aperture of the secondary ion beam so of course if you reduce, you use a small aperture slit, you will reduce these aberrations and will (set an ?? on the) entrance slit because as here we use a beam waist. It's a strange thing, the beam waist. It's something you never know what happened inside. You have (trajectories) coming from everywhere; so that means when you reduce the entrance slit, so you cut more and more in those beam waist, you will reduce also the angular aperture of the beam, to a certain extent, so the energy of the beam. It means that this parameter is under control of three elements, at least. The next one is a chromatic aberration, which is also connected to the angular aperture of the beam and to the relative energy spread of the secondary ion beam so that is under the control of the energy slit, of course, it's a most efficient elements that act on this kind of aberration. LF4, which is in charge of chromatic compensation, and we'll speak about that; the energy slit, because the energy slit is also an action of the energy spread, you find after the energy slit, so it changes the energy distribution in the beam and, of course, the aperture slit, because here you have the angle ?? is (in the formula). So after that you have higher order of terms. I don't want really to speak about that because you can find – we already did some metrics describing the mass spectrometer with an excess of 70 terms – so you can find everything if you have some interest in that. I have the metrics there just to show you how use it is. So I don't want to speak about that. I just will give you some very small – as large as you want – some information second order aperture aberration but in the other planes. So that means the secondary ion beam has an angular aperture in the radial plane, the plane where we have the focalization, but it has also an angular aperture in the vertical plane, and these angular aperture give you aberration in the radial plane. So that's an angular aperture in the vertical plane that gives you aberration in the horizontal plane. And these kinds of aberrations are under the control of the hexapole LF2 and LF5 but it depends – we give you that. I will start with the chromatic aberration, it's much more easy to explain. Here we have – I will do a smaller drawing again. So when the beam enters in the mass spectrometer it has an energy spread, and of course what we need to achieve is what we call double focalization, which is a mass spectrometer we have; so angular focalization and energy focalization; so what we want to have it's at the exit and the mass line all the energy at the same point, the focalization point. So what we have is something

like that. We have the entrance slit there, focal plane of the mass spectrometer, and here we have in this beam different energy – let's say we have three energy – E1 being the highest energy. All this energy will be sprayed at the exit of the electrostatic sector, like that, E1, and it seems to come in one point which is a chromatic point of the electrostatic sectors which is the distance which is 1 radius of the electrostatic sectors. That's normal the way we use electrostatic sectors to disperse the energy. And here what we need to have is all this energy coming there. So in the magnet we have also a kind of a chromatic point – so if you send all energy on this chromatic point, at the exit you will get something free of chromatic aberration. And to do that we have two elements – optical element – LF4 and Q – and we are able to tune these two elements to compensate for chromatic aberration – LF4 is there and Q is there (Slide #14). But Q has another effect also. And the main effect of Q is to do the focalization, the aperture focalization, the first order focalization. That means that you need to tune Q to have the focalization of the beam. If you take 2 angles here, you need to be focalized there, of course. And that is done for a given Q; and then you have a free parameter, which is LF4; LF4 act mainly on chromatic compensation because if you look at how it works there roughly it works like that. We do an image of the entrance slit through the electrostatic sectors – and this image is set there where we have the energy slit and LF4 is very near from this point. That means that LF4 will have a very low action on the first order focalization; will not change so much the angular focalization. But it will act on the chromatic compensation because it has to conjugate two points which are really ?? situation for LF4. You see that Q is there. So how to do that? There are two ways. When you don't want to do that, to do the best you can, just change LF4 and try to find the best mass resolving power you can by changing LF4. You will be not too far away from the right setting. If you want to do the best, achieve the best, because you need the highest mass resolution you can expect for given settings of the mass spectrometer, what you have to do is a slightly different job; it's not so difficult to do. So you will test the chromatic compensation by changing the sample voltage. We will choose three different voltage for the sample, that will give you three different energy for the beam, and you will check at the focal plane there if there is some change in position of the mass line; if there is no change then you perfectly compensate or there is some change and there is something to do on your LF4. So exactly what we have on the graphs there (Slide #15). On the axis here you have the offset of EOW – it's not easy to understand when you don't know what the NanoSIMS is – EOW is the last electrode, which is on the immersion lens, the one which is very close to the sample, and it's connected to the sample. The –

FH: So I just add that by 7.5 volts plus 7.5, -7.5, and here you just do high mass spectrometry on the focal plane and you look at the position of the mass line, it's the center line on our software, and you record that with different LF4 and what you can see here is that you have for this LF4, which is 70, you have some change, then the change will decrease when you decrease LF4 – here it is quite perfect and then, of course, it moves the other way, and so on (Slide #16). So what you can determine here is a slope of each – it's kind of a linear regression – and if you do another graph with a slope versus LF4 you can find an LF4 where you have no, where the slope is zero, that means you perfectly compensate for chromatic aberration; in this case it will be something like 1640. It's very simple and it works very well. There are no difficulties about that; it's easy to do. And just use ES3; don't set the energy slit, of course, because you need to see chromatic aberration, so don't cut the bandwidths, the energy bandwidths of the mass spectrometer. Don't use any aperture slits, too, because you need to

have the angle to have the maximum effect for the chromatic aberration because the chromatic aberration is $K\Delta E/E$ so you need the Δ to see that; so that has been made on a silicon wafer without any problem. And of course Q remains unchanged.

GS: I agree completely with what François said except for one point. He talks about chromatic aberration and in this experiment, in fact, you reduce to zero the chromatic dispersion, and what remains after that, it's the chromatic aberration; when the dispersion is killed, you have the true aberration, which is the term you mentioned – $\Delta^2 E/E$ plus $\Delta E/E^2$, which is an older aberration you don't like to talk about, you put it in your parenthesis.

FH: Yes, I agree with you if we were at the focal point but it's never the case. You more likely compensate the chromatic aberration instead of only the chromatic dispersion. Okay – that's open (for discussion). Any other questions? And as Q can change, the value of Q depends on where you are on the focal plane, what kind of ions you are using, what kind of settings you are using for the mass spectrometer. Very often you need to change Q according to these different parameters. If you change Q LF4 will change because Q has a huge effect on the chromatic aberration and chromatic dispersion and LF4 has a very, very small effect. So it's relatively pleasant not to have re-tuned LF4 each time you touch Q . So in the software, in the set-up, you have a way to attach LF4 to Q . It means that when you change Q it will change LF4 for you. Of course you have to determine the relationship between Q and LF4 in your mass spectrometer but it's not very, very difficult. Just change Q and you reduce it to the previous experiments to determine the optimum LF4. I don't think it's used by anybody. Frank, you don't use it? No. It's there but – and it is not so difficult to tune LF4, it's not really used by anybody. Can we stop now?

CL: Sure.

FH: I continue after the break.

(session break)

FH: Okay, so coming back to aberration there. I just want to speak a little bit about second order aberration (Slide #17). So this aberration we correct that with the (hexapole). With the (hexapole) is used to correct this second order aberration but they are relatively difficult to see; that means that it's relatively difficult to have a clear view of what is the action really on the beam. So what currently you can – I will draw something – so when you are doing in the mass spectrometer, when you scan the beam, so we have two plates in front of each of the detectors with the slit, exit slit, you have the beam coming there, you have two plates and you can scan the beam in front of each detector, in front of each exit slit in front of the detector, and what you've got, of course, is something like that. So of course here that's the intensity and that's the plate voltage, and when you get something like that, that means that here the beam is outside the slit, here the beam is inside the slit and exit from the slit. Of course, what we are looking, we are looking to this part of the mass spectrometer that shows the beam shape and what happens when you have this second order aberration? You have something like that, some wings on the mass line, that's because that increases the width of the mass line and decreases the mass resolving power even if you reduce the energy dispersion by using the energy slits and that is mainly second order aperture aberration; that's exactly how I can explain that to you. That is an

electrostatic sector, which is mainly responsible for this second order aperture aberration. And I will just explain to you how it works here. If you take different angular aperture there, in the beam, of course the other side; if you look at what is going on there, it's like that, so you have the axis, the focal point, and here which is the image of the entrance slit, which is roughly the plane where you have the energy slit, and when you increase, so with a small angular aperture it will be focalized there, with a larger one it will be focalized there, and with another one, which is larger, it will be focalized there, which is exactly what we call, if you have x there, x is proportional to α^2 ; α^2 , α being the angular aperture beam at the entrance of the electrostatic sectors; that's typically second order aperture aberration. That means that if you, so here is the entrance slit, if you take a small aperture slit like that, and you move this aperture slit in front of the electrostatic sectors, you will select a small beamlet there and you will change the aperture of the beam, you will describe that, starting from there, decrease there, and increase again. So that is exactly what happens at the exit of the central electrostatic sectors. Of course it happens in the same way on the focal plane of the magnet because the magnet also has second order aperture aberration and you can find that. That's exactly what you are seeing there (Slide #17). So here is AS5y, so in the horizontal plane, so A just moves a small aperture slit, ES5 is for because we use 40 by 40 micron aperture slit, and when you can see, of course, the intensity is going up and down, center of the mass line is there, and here you can see the central line, the mass line moves like that, it's exactly the same effect we have there. For large aperture positive angle it is there, and then it goes down to zero and again to high centerline. So that's very difficult to see because it's lost in the beam waist and to see that you have to be right at the focalization otherwise what you will see if you look at what happens there, you have all this, here you have the mass line focalization which is a beam waist, something relatively intricate is there. If you are not at the right position what you will see instead of seeing this perfect bubble, looking like $K\alpha^2$, you will see something like that – straight line and you are disappointed because you see – where are my secondary order aperture aberration. It's just because you are not at the focalization plane and what you look at is first order de-focalization, not second order aberration. So it's relatively difficult to find the right settings for Q to see that. So we can try but it will be difficult. But however it's a way to see second order aperture aberration and, of course, what you have to do to tune the hexapole, is to reduce the amplitude of the ???. If you don't use the hexapole you will find something like that; they're huge. Instead of having the (wall) second order aberration within 4 micron, which is relatively small, compared to the mass line which we have, also according to the fact that these points, you don't have a large intensity in this point, they will not contribute to the main part of the beam. So it's just to show you that it exists, that you can find that but it's relatively difficult, so that means that to tune the hexapole, the best way is to tune the hexapole, and to try to reach the highest masses of power that you can reach because by changing the hexapole as you are doing now. On the other graph (Slide #17) is exactly the same but instead of looking at what happens for the aperture aberration in the radial plane, I did the same in the vertical plane, which is a $K\alpha^2$ term of the first relationship I showed you. This one, you have the same kind of term, this one; this is angular aperture in the vertical plane that gives you second order aberration in the horizontal plane so that the angular aperture in the vertical plane that gives you aberration in the other plane. And this one is exactly the same, the same kind of shape – you see this relatively good ??? there and again the intensity in the vertical plane which is there; so just to show you that it exists but it's very difficult to see. Did you try, Frank? No. Any questions?

GS: You saw on those pictures, they are fairly symmetrical which means that if you are a little bit out of center with the finish of the beam you will have the wing, let's say the left wing of the aberrations, and so this shows that really the beam is properly adjusted so that you have a symmetric figure, which is the smallest aberration effect you may have. The same, of course, François mentioned it on this figure, but the same is also true from the vertical aberration, which means that the mass line, instead of being a straight line, is slightly curved like that. And if you had the beam far apart from the radial plane you will have something like this; here you are in a good position and then you go like that. So I think it's important to at least when you send an instrument to a customer that you have made this thing before. I hope so.

FH: No comment.

HV: If you fix this problem once, is this problem once, is that fine forever or you have to do it all the time?

FH: No – what we use to – I must explain that, maybe. For this vertical aberration we don't have any corrector for that. The hexapole doesn't act on that. On the contrary, it adds some \square^2 aberration when you compensate \square^2 aberration you add some \square^2 aberration but what we did is that as we have a slit shape for the beam, so in the vertical plane, instead of to do a focalization in the entrance slit, on the contrary we open the beam and we try to enter in the mass spectrometer with the beam as parallel as possible to have \square equal to zero. So we don't have any second order aperture aberration coming from that. Exactly the way we set LF2, you see the slit lens is one of the two slit lens which is in front of the entrance slit, they are there for that; to control the height of the beam and the way we enter. So LF2 is there and LF5 has the same action as the entrance of the magnet. It is there to control the way we enter in the magnet to be right parallel, as parallel as possible.

WL: This is more of a hypothetical question. For many of these alignment procedures I get the feeling for how to do it; it's pretty straightforward once you have the details written down, you can follow the recipe, but some of the steps are tedious because you make an adjustment, you take a measurement, you make an adjustment, you take a measurement. Are there, again hypothetically, if you could place an imaging detector in your column – hypothetically – where would you put it?

FH: No.

William Lamberti: No?

FH: The simple –

WL: Only as an alignment –

FH: The simplest imaging detector you can imagine is a CCD detector – channel plate detector. The width of the mass line we use will cover only two or three channels of your channel plate; you cannot expect to see any details. The other way to do that is to do like zoom optical elements – to do a zoom of your mass line – and what you will see is an aberration of your zoom instead of seeing the aberration of your mass line.

WL: The question was more hypothetical – it was not to ask you is it possible. It was more if you had a place – if you thought of it that way – to make the alignment more efficient –

FH: We tried it at the very beginning of the NanoSIMS, there was a channel plate; everything was there. On the ?? instrument you will see that there is a tube under the multi-collection chamber just to being able to see inside the channel plate with the ?? screen – we forget it. Each time we use it, it was very difficult to see something because it's just a very narrow 10 micron by 50 micron height slit beam, so it's very, very small.

WL: It's just too small. Okay. Thanks.

FH: Now, Peter –

PW: I was just wondering with the graph on the left, is that a graph with the Hexapole well aligned if you would have the Hexapole poorly aligned would you see a more pronounced effect?

FH: Yes. If you change the hexapole value what you will see is something more pronounced like that so what you need to have is something as small as possible there. So when you change the hexapole value you will see an increase. Sure. But again, it's not the way the tune the hexapole, because when you will change the hexapole, you will move the secondary ion beam a little bit and the focalization will vanish and so again you have to find the right focalization and spend weeks with that.

GS: I want to just make a short comment on your question among how to look at those things. If you put a channel plate, it's not only that you will not have the resolution, but also you will not have the dynamics range, which will be enough because these are wings and wings you will see something bright and the wings you won't see them. So the only way I think such things could be done is to use all the method – it's a method used in optics and it comes from Foucault, from the scientist, that it is to make shadows. So you look at the beam on the screen and you make shadows, you shadow the beam, and from the way the shadow moves you can tell where are the aberrations. But it would be – and the shadow must cover a large region and it will be difficult for intensity reasons to do it. I think it's not easy, but it's probably the best way to do it; it's less expensive in efforts.

FH: I will just say a few words about that because Georges explained that to you in detail this morning. Just we want to go rapidly. (Slide #18) So aging effect – you see that – Georges was saying that after a certain ion dose on the electron multiplier you will see the maximum distribution moving to the axis and that is just related to the –

CL: François, for the few of us here – where do we jump here –

FH: Electron multiplier. Sorry. I jump at the end of the mass spectrometer and I just want to speak about the electron multiplier a little bit just to give you some numbers about its aging effect and I just want to speak a little bit about the QSA – quasi simultaneous affect – the experimental part and so that's of use, it's very easy to see, just leave the electron multiplier with 500,000 counts during one hour and you will see the pulse height distribution moving. So this kind of evolution can be fit with some kind of semi-empirical (ratio ??) saying that just that the

maximum of the pulse height distribution will decrease with time according to an exponential law with some fitting parameter which is here 2D (Slide #19-20). So that means that it's not only the maximum of the pulse height distribution that moves but to a certain extent the shape of the pulse height distribution itself can change a little bit. I don't want to be too long about that. Just again a short word about what we change on the NanoSIMS. Four years ago or something like that – three years ago – we were using a very small electron multiplier which are still used on the ?? instrument and this small electron multiplier had a very strong aging effect – very, very strong. So we just move to another type of electron multiplier just by enlarging the dynodes and why we did that is just because it was relatively known that these aging effects were connected to the electron density of the last dynodes. And on these last dynodes you have very high electron density and it (deposits) carbon; it does for SEM – if you're on an SEM you send an electron on a flat surface on a silicon wafer and you see some carbon cracking; you see some square, black square on the sample. It was certainly the same on this kind of (EM) so we asked ?? to enlarge the dimension in two directions – not the widths because the widths we absolutely need to have small widths with electron multiplier but we increase the dimension of the electron multiplier and instead of having one, the fitting parameter in this kind of region, we are now able to have this kind of feature for the electron multiplier and we have reduced the aging effect by a huge factor, something like 20 or even more. But it still exists. So, the problem is when you are doing isotopic ratios, for example, very often you have one main isotope and one or two or three other small isotopes and what happens is that the decrease due to aging effect acts directly on your isotopic ratio in the same way; that you see the isotopic ratio decreasing with time due to the fact that the main isotopes, the efficiency of detection, the efficiency decreases with time and just to have a real idea of how can you estimate how fast it is. So you see here you have this fitting parameter for the isotopic ratio 2 R and the fitting parameter for the aging effect on the EM is a scan of relation meaning that if you have 20% decrease of the maximum of the pulse height distribution you will have 1% of decrease on the detection efficiency on this electron multiplier, so it's a huge effect (Slide #21). That's not something you can – you have to take care about that. So 20% is a lot; to decrease by 20% on the electron multiplier, typical electron multiplier with 500,000 counts will take maybe half a day. So you have to take care about that. And a good way to estimate that is a factor of 20 or it can be 25 – it's roughly something that you can use to estimate the effect – it depends, you have to choose first to determine what kind of precision you need and according to that you have to check your EM relatively often or not. That's all on that. So QSA effect – I don't want to explain again what Georges explained to you this morning. I just come back to this formula which is just (Slide #22) a simple way to explain how you have to correct a number of counts you have on your computer, saying – okay, it detects 100,000 counts; but if K is 10% you have to add 5% to this count, because you miss some ions due to the fact that many atoms with 2 ions or 2 or 3 secondary ions decrease the aberrant counting rate of these ions. So in addition it's why here it's (Kcor) used instead of (K exp for K) as you expect you have a difference between the number of counts you have detected and the true number of counts. And as you need to know the real K, to determine K you need to have a secondary ion count, and to be divided by the primary ions. If you use the one which comes out from the ?? it will be not a true one because there is some counts missing due to the QSA effect; so you have to correct the K and to find the right K because by this small, very simple formula. You can come back to the article by Georges for the explanation of that. But what I did here is on sulfur, just to try to see if this very simple formula can be applied to that (Slide #23). So I did on sulfur – 34 to 32 isotopic ratios; it's not difficult to do, that means that there is not very big in

difference, even in with masses having power of 3000, it's enough to work. And I changed the K value by changing the slit we use in the mass spectrometer – so the primary ion beam remained constant and you have a large ES3 and without aperture slit without energy slit, so you get something like 20% which is very high on sulfur, the (useful lead) is very high there and you can decrease K by just using more slit, more aperture slit, more energy slit and so on. So to do this kind of job, to just to avoid strange effects, I used different slits, I used different EM, not only the same two EM – because you can some effect due to EM – and by doing that what you can see is that if you do a linear regression on that you will find .7 instead of .5; so this point is open (Slide #23). That means that either the measurements were not well done, which is possible; either the Poisson statistics that had been used to determine that is maybe not the right one; either, I don't know, there is something else. And at least we must do something for that because on the NanoSIMS you reach very high K, so you cannot imagine that you will not take care about this problem. Of course sometimes it has not so huge effect; for silicon you will stay around there but for many elements you will get a high K and you need to know what kind of correction you have to do. So this point is still open. It's quite the only measurement that has been done with this very high K; so Georges does something on silicon but the K was more likely 1 Poisson (?percent) or something like that. But at very K, that's the very first measurements; so we need to work on that, we need to redo that on different ions, in different conditions, on different instruments, but that's an open point. So if you have some time in your lab, take a silicon wafer, and try to do a 30 to 28 ratio, which is not difficult to do, it's not so big in difference and try to do something if you can.

GS: Okay, I just wanted to make a small comment which is that if those measurements would have been made with the Faraday cup we could have even a better check that at least, say, you would demonstrate that there is something like a QSA effect really existing; the other formula is a formula and when you changed points, since you changed your slits, you changed many things to reduce the K, and you are not sure that the isotopic fractionation stays the same – that would have to be proven – the best way to prove it would have been to measure 32 with the Faraday cup.

FH: I did it on silicon – it is perfectly flat. You know that because it was in poster.

GS: It's perfectly flat but with the same it is also .7?

FH: I did that on silicon just instead of using 2 EM I used one Faraday cup on the 28 and one EM on the 30 because on the silicon K cannot be so high, it was emitted to 10+ but there is no QSA effect.

GS: And what was the coefficient of the K?

FH: Nothing – with the Faraday cup you don't see anything.

GS: Yes, but you could have done it then with the –

FH: No, no, because that's to be perfectly transparent I would say that side results; at that time I was not absolutely working on K, on this QSA effect. It's something I just extract.

GS: Yes, but the experiment is possible.

FH: Oh, yes, sure. I just need time and instrument and a sample.

Unidentified Speaker: You have a standard to compare to, right?

FH: Yes but look at the value there.

Unidentified Speaker: It's huge.

FH: There's no question about ???. We are not in per ml problem; it's 120 per ml, it's 12 (Poisson ? percent) effect so the standard there – it's just, I don't speak about standards, I just say, okay, I do a straight line and I take the standard the right or the true value as the intercept of the y axis just – I don't know if I answered your question but there is no standard.

Unidentified Speaker: There is no standard here but if you're trying to do a high precision measurement you'll have a standard which is working at roughly the same K, right?

FH: Yes, but K can change according to the way you implant cesium, for example, if you use cesium – the way you cut the beam and so on –

Unidentified Speaker: Okay. This is a humungous effect –

FH: Yes this is a big effect because the QSA effect is a very big effect. If you have K in order of 10 Poisson or 15 Poisson you will have to correct that by 7 percent which is a huge effect. It's not a (dead time) correction is something you do at the lower percent level – here it's a very, very huge effect. So of course one solution is to put slit in there – but you kill the transmission and you will get something correct – but if you want to use (whole) efficiency of the instrument and working at high transmission you need to know something about this effect. It's not always the case. Sulfur is a perfect example for that – oxygen on a ??, that's also a good example but it's not always the case.

Hojatollah Vali: But it means each time you have a sample you have to do this exercise here?

FH: No. What you can expect to have is some general law, saying, okay on this kind of sample the correction is .7 or .6 – for the moment it's relatively new; this effect has been demonstrated by Georges two years ago and for the moment – as I said it's the very first experiment, very first measurement on that at high K; at small K there was some job done by Georges but at high K these are the very first measurements. We have to work on that.

HV: But I'm concerned if you have, for example, a biogenic pyrite, it would have different ratio than – that is the application – if you can decide that you might resolve some of the problems that we have –

FH: I don't know.

GS: There is simple way to cure all these things is to measure with a Faraday cup if the current is high enough or that is the way I would imagine it to go if you have this type of situation; unless you would need to have any value of K to make a first approximation and then

you see what I don't know is the expression one wrong, that could very well be or when we have such high K are we sensitive to some other effects – and this is not settled. I have not such a wonderful instrument with such high K – I'm working with 1% and I am very happy.

FH: I just want to do another comment. The Faraday cup can cure the problem as long as you don't have to use a very high (level, lateral) resolution because the case the ?? will be low enough – you cannot use a Faraday cup because you will have too much noise. So in certain situations it could be a problem. Of course, the Faraday cup is one you can use to consider that completely. Just to say that there is an open problem there – you have to take care about that because sometimes you can find with that positive mass fractionation which is strange, at least. I don't want to spend too much time on that – I can come back if you want but just to say that this QSA effect has also an effect on the pulse height distribution because if you look at, for example, the pulse height distribution of 34 sulfur there, which is there, the red point, if you imagine that now that you are looking at the difference with the 32 S pulse height distribution which has (big) K – what does that mean? It means that you will have less event on the EM with 1 ion and you will have more even with 2 ions, because K is higher. That means that this part of the pulse height distribution will decrease and this part, which is roughly two times the mean, will increase. Exactly what you can see there on this comparison, you see that 34 sulfur and the 32 has decreased, of course they are ?? to the same count rate. And you see that on the 32 you have a tail there which is higher ?? of course that's for certain different reasons the precision of the 34 is not high enough to be able to be absolutely sure of the difference but however there is a difference and that can be explained by QSA effect by using the semi-empirical model of (cesium). And here you can see that this model is able to reconstruct the 32 S pulse height distribution with some K according to the K we use in the experiments, and without K the pulse height distribution will be there (Slide #23). But just to say that there is also an effect on the pulse height distribution, it can be visible at high K but it has no effect on the threshold position, it can continue to work as it was working before, there is no huge effect on that. So I don't want to spend too much time on that. Now I want to come to another open problem and to come back at the entrance slit. When you look at the ion pass starting from the sample and going to the entrance slit, it's a long travel. And here if you have, and we have some very weak magnetic field coming from the ion pump from mechanical which are not absolutely magnetic, you can expect, and there is some magnetic field, the weak magnetic field, along the pass, ion pass, and this magnetic field will lead to have mass fractionation of the beam before it enters in the mass spectrometer. That means at the entrance slit the beam is already mass dispersed which is not a good (news). And here you can see, for example, a graph which is just recorded the entrance slit on two species – for silicon 28 and carbon 12; so we scan the beam in front of the entrance slit with cy and we will record the intensity of these two mass lines (Slide #24). And what you can see is that the two mass lines are (on top) at the same position – the 12 is there and the 28 is there, so the difference is not so huge, you can have both in the slits, but there is a slight difference there and it's not good for isotopic ratio for example, because of course between carbon 12 and 28 there is a huge difference in mass but if you think about 28, 29 and 30, they are not at the same position. Of course the precision to see that is – we need a too high precision to see that – but there is some effect there and when you will cut the beam with the entrance slit, it will not cut in the same way – 28, 29 and 30, so you will have mass fractionation there, changing as the ratios of silicon there. So that's something that we also discover not very long ago – some months ago – and how can we cure that? So we cannot suppress the ion pumps which are there; there are two big ion pumps on the NanoSIMS in charge of pumping the analysis chamber and

the main central column chamber – so that's it; that's very big. So what we can do is to add magnetic field, vertical one and a horizontal one to compensate this weak magnetic field and to move this beam – carbon 12 and 28 at the same place. They will be not at the same place – so they are there and by adding this magnetic field they will do that and that's exactly what we did – so here you can see these two graphs (Slide #25). On the x-axis you have either the horizontal field we add or the vertical b field we add and here you have the two positions of carbon 12 and silicon 28 at the plane where we have the entrance slit –

FH: The entrance slit and you can see there is a slight difference between the 2 cy, you need to have or the two mass line; then you increase the vertical Bfields, that means that these two beams are moving in this direction and slowly you will find a position or value for this vertical Bfield that will cancel this mass fractionation effect at the entrance slit. You will get all mass line, because it's not only true for carbon 12 and silicon 28, it's also true for all mass line, for all masses, you will have settings for these coil that vanish that effect. And it's also true in the vertical plane where you have a difference in P3 – P2 and P3 in the vertical plane and you can have a position or setting for this coil which vanish this effect. So this system has been installed on your instrument, Frank, in Washington, on the second one in mine – it's under test now. We need to prove that it increases the productivity of isotopic ratios and so on so we are on the way to work that and it will be retrofitted in all instruments – maybe not before the end of the year but in 2004. The software is already done.

HV: And this one if you fix it it's good forever.

FH: Yes – I don't know. That's a good question.

HV: You are discovering almost every day a new problem that you have. The good thing is –

FH: It's my job.

HV: Yes. That's good but you can upgrade those instruments without any problem because by doing that if you want to fix the –

FH: Our policy on the NanoSIMS – I don't want to speak about Cameca. When we found the problem like that, it's a new instrument so of course there are some problems for sure. We try to retrofit all instruments for free because it's our fault – that's for sure. And there was, for example, a big problem on the cesium cooling system – we replace all these cesium cooling system, which is a lot of money, on all instruments. There was some other problem, too, and so for the cesium cooling system it is not done on all at the moment because the one of Jean-Luc is not done at the moment but we are one the way to fixing everything and that will be done, too. That is more simple – it's just wiring and nothing – the software is already done for that now. Now just to say that everything is not perfect on this instrument if there were some people thinking that. There are some side effects.

Unidentified Speaker: I was just going to say that you were questioning whether or not this a permanent fix – you need to be obviously aware of this because if your laboratory conditions change – replace a pump or a motor or somebody puts something in the room next to you – it could have an effect on these measurements so if there is a fix for it that's good.

FH: After that I will switch to the second part of my talk which is more likely on what we plan to do or what we have done or what we plan to do in the near future on the NanoSIMS and maybe it can be of some interest for those people who already have a NanoSIMS. So for example here we will – and it's already designed and quite made – we will motorize four elements – so the D1, which is very often changed, the entrance slit, the aperture slit, and the hexapole (Slide #26-27). And that will be of course made under the computer control and so on. What could be very, very useful is to have different position between the pre-sputtering part of the analysis and the analysis and that is something which is very useful in the NanoSIMS – on any instrument – being able to launch an analysis and say – okay, I will pre-sputter the sample with high current, with different settings of the primary column, without the diaphragm D1 to increase the current; then after this part – can be one minute or two minute – I will come back to another setting, saying – okay, different way to tune the primary column and different settings of the diaphragm – so that can be very, very useful for analytical purposes. Of course it will be completely – we will have pre-set position and so. And it will be fully compatible with existing instrument. It means that it will be available for any instrument. So there is nothing else to say, just to show that. So in detail it's the vertical movement and horizontal movement on each diaphragm except that the vertical movement can be relatively simple and relatively slow because you just have to adjust a little bit the position. Of course the y movement is a little bit more difficult because you need to be very fast, you don't want to wait one minute to remove D1, and you need to be very precise. For example, in the entrance slit the position must be in the range of 1 micron, not more than that. One micron is very fast, it's not so easy but – so it will be available in 2004, the middle of 2004. Another development we did, it has been done for ?? University is to change one detector and being able to detect at the same time – so using all the capability of detection of the multi-collection on the NanoSIMS. So what we have changed, we have changed the distance between – oh, yes, maybe I will start for those who don't know the multi-collection – I will explain roughly how it is. So that's the magnet and the electrostatic sector is there, the entrance slit is there, so the beam enters the magnet there and all mass lines are spread along the focal plane, which is there; and all along this focal plane we have one Faraday cup which is attached to the trolley 1, on this trolley 1 we have 1 EM, another EM, another EM, another EM, so we have four moveable EM, another EM fixed there at the radius which is 520 and a big electron multiplier there which is at the radius of 550. That's a common multi-collection schematic. For this guy what we did we changed the position of EM5 and of the (loud) detector so being able to detect at the same time uranium 238 and uranium oxide 254, which is required for silicon measurements. So after that on trolley 1, 2, 3 you will detect something which the (??) elements on which doesn't need any change and on trolley 2 they ask us to develop a double detector with 2 EM, being able to detect at the same time 204 lead and 206 lead. And that's relatively difficult to do because the minimum distance between 2 EM, or 2 detector, is now 8.8 mm and the distance between 204 and 206 is 2.4 mm so it is impossible to put 2 EM close enough to detect that. So what I did – something like that – so you see just the head of the detector, the double detectors, so you see the two mass line with the 2.4 mm distance. There we will have first three plates – one, two, three – that can be powered indefinitely; we'll bend the beam in this direction; then you have the slits there, the two slits, the focal plane is there, then again two parallel plates to re-bend the beam in the other direction and finally the two EM that are at a distance of 4.5 mm there, back on the side, to detect these two mass lines. I hope it will work. So that's a very small design and we did it so it just looks like that – maybe the light is too high – but you can see here the three first parallel plates there, the slit assemblies

there, the two other plates which are after the slit and the housing for the 2EM, which are there. So that will be tested in the middle of October. Just to say that if you think about something, special detector or something, we can think about that. Here we have another development, which is not started now, but I hope we will start with that; it's something that has been asked by two different teams – one in Houston, for NASA; and the other the Carnegie Institute of Washington – is to increase the capability of isotopic ratio measurements on the NanoSIMS. Up to now we are limited to silicon, that means we can detect 28, 29, 30 at the same time, so simultaneously, but we are absolutely unable to do titanium isotopes because they are too close. So these two teams asked us to a new multi-collection system, able to detect up to ion which is 58 and this is an old slide but maybe we will increase that to nickel to 62, to mass 62; so being able to detect simultaneously all isotopes of nickel and of course all isotopes of all other elements with lower mass than nickel. So it's a big change; so one solution will be to increase a magnet by a factor of 2.5 which is crazy because it's already a very big magnet; so what I choose instead of that is to use the same system I use on the 1270 to add these small electrostatic sectors, just after the slit. In fact you have the detector, which is the largest part we use on the NanoSIMS, this is the detector perpendicular to the focal plane. With this small electrostatic sector and so by using that and by increasing the magnet to 650 mm instead of 550 now we will be able to do that. So I will show you how it works. I forget to say something else. And in addition they want to have the possibility to use either a Faraday cup or an EM on each trolley, on each detector. That means that we have to add a Faraday cup attached to the EM but not like that, so we have to set the Faraday cup in the vertical plane so that increases the minimum distance between two different detectors. So here – for those who know the NanoSIMS it is easy to recognize the slit there. So the beam is entering there. Here we have the two plates; they are not drawn but they are there; the two plates that we use to scan the beam in front of slits, the slit is there. After that you have these small electrostatic sectors to bend the beam, some plates, some deflecting plates, and finally you have the detector here, the electron multiplier there, and inside of the electron multiplier we will add a Faraday cup, a small Faraday cup there. That means that in the front plate of the electron multiplier, in this front plate you have slit there, will add another slit hole to leave the beam going through in the Faraday cup. To do that we will be able to move all that green part in this direction; so either you use the EM and you set your detector there, or you move everything, all that part, and you set your Faraday cup in front of the beam. And that will be controlled manually; you have to open the multi-collection to choose the setting. I will not do something in a vacuum because it's too difficult. So that's something we are studying to look at how it will be with six detectors, because we will have six moveable detectors like that, it will be like that, and the minimum distance between two detectors will be 5.8 mm instead of being 8.8 mm – so I hope we will do that in 2004.

Unidentified Speaker: (Inaudible.)

FH: No, because here you see that the distance between the focal plane and the end of the chamber has increased a lot. So we will have re-design the multi-collection chamber, to redesign the magnet; the cranks maybe have to be redesigned, too, and so it's a complete change. If you want something you have to buy the whole magnet. That's possible. Yes, it will be fully compatible.

GS: I don't understand well – you could reduce the distance between the multiplier just by using those –

FH: I can draw something. Now on the NanoSIMS you have the focal plane like that, ions are coming like that, and we have all the system like that; so that's, for example, two detectors. And that's not the best way to do that; the best way is to have the detector like that. They are perpendicular to that and to that. It's absolutely just – with this kind of settings here it's 8.8 and here it will decrease to 5.8 just by adding the small electrostatic sector. Exactly the same on the 1270 because here on the 1270 it was absolutely required because the maximum – we need to be able to detect lead isotopes, so it's far, far away from there.

Unidentified Speaker: (Inaudible.)

FH: Oh, yes. Absolutely. The 1270 magnet is an isotopic multi-collection system; that means that you are able to do lead isotopes, carbon isotopes, (boron) isotopes to a certain extent but never can you do carbon isotopes and silicon isotopes at the same time so that's completely different. Here on the NanoSIMS you can detect that something you have there – the dynamic mass is 18, that means you can detect mass 10, and under 80 at the same time. On the 1270 they didn't make mass ranges, nothing, it's very small. It's one out of 12. It's absolutely different. In addition on the 1270 it's not a true – I don't know if I know – there are other aspects which are completely different on the way it focalizes the beam and so on.

GS: I hate to criticize the 1270 but this mass spectrometer here is a truly double focusing mass spectrometer all along the focal plane. In the 1270 it is just an approximate double focusing mass spectrometer along the focal plane.

FH: I don't want to say that but it's true. In 1270 there is a focal point, there is no focal plane. But it works; that's a very good instrument – there is no problem. No, it's really a big difference. It's an elemental isotopic multi-collection system.

Unidentified Speaker: (Inaudible.)

FH: Yes, but bigger magnet – it's linear with the mass – not linear, but if you want to increase, if you stay at the same distance with the mass line, the minimum distance being five, to go up to mass 100 instead of 50 you have to double the length. It's too big and after that you have a problem to align the detector along the focal plane because the instrument – I don't want to do that. And another problem is that when you increase the length there, you increase the height of the mass line, and you will get problems with that – aberrations, and so on – so I don't – no. That's the maximum we will use.

HV: I think we discussed this once. I was interested if there's any hope to have a cold stage with the sample. Because in biology we are interested in cryo –

FH: You want a cold stage. Why not? But we will not do that by our own – it has to come from outside – saying, okay, we will sell three instrument or four instrument or one instrument with a cold stage and we will –

CL: We did once a cold stage and an electron probe and there is much, much more room in the NanoSIMS so I think there will be, compared to the electron probe, no problem to have one if people want to pay.

FH: You have one guy okay with this. It's not easy because the sample is at high voltage. The room, the space is not a problem – we can increase the – this chamber is not so big, we can increase that – but we know that there is some problem. We tried already in the 4F for a biology lab and it was not a big success. The transfer of the sample from outside and so on and so forth – it's very difficult and you have a bubble – you have vibration and so on.

GS: I don't know if it is a very good cold stage but at the last SIMS meeting a man whose name I have a little bit forgotten working in Germany he made a cold stage on the 6F for geological samples and he claims that it is working well but I don't know – vibrations maybe he is not so much concerned by vibrations but he was working at the high voltage and he had good design for –

FH: I didn't say that it's impossible – it's not nothing – it's just – okay, we will do that – come back in three months it will be okay – that's a big job. It's possible of course, but it's not nothing. Any questions?

WL: A couple of comments. I'm not a biologist so I don't know the details but my expectation will be for a cold stage you would just need to be below the freezing point of water – how cold do you need to be?

CL: The answer is the vapor pressure and you have ?? down to -90 C and so you want to be much below -90 C.

HV: No you don't need necessarily nitrogen but the cooling fixation is different – you need 100,000 K per second for fixation, not to induce ICE, but the temperature of the sample should never go below 86, I would say, or 90 – that's the crucial point. You know what I'm saying? How you transfer the sample shouldn't go below -100 degree or above.

Unidentified Speaker: Any news on the ion source development?

FH: I continue to work on that.

WL: There was some discussion at the SIMS conference in San Diego about your focused electron beam ionization of the cesium source?

FH: It's not ours – it's a collaboration with this lab here – but we are on the way to do the job but there is no real result for the moment. The general idea is that but there is no result for the moment. We continue to work.

CL: Are we finishing so early? George, do you have any comments?

GS: On what could I comment? Well it's interesting to see how the allotment makes the instrument more powerful – bigger magnet, more detectors. I think that the detector is something very sensitive and I hope that we will be able to improve the electronics on Faraday cups, for instance – have a very tiny Faraday cup, for instance, so we could measure small, adapt those Faraday cups with electronic parts added in the Faraday cup so that we can have a low noise and make more measurements with the Faraday cup. But the Faraday cup will never make us able to make imaging, for instance, because it's too slow. So for imaging I think we will still

be obliged to use something like electron multipliers. The point with electron multipliers is that if we could make our own electron multipliers it would be a lot better. Unfortunately it is too much work and no manufacturer would be able to do it at a reasonable price; but the electron multiplier they have so many surfaces in it that it's impossible, practically, to control all the surfaces so you may have a very good electron multiplier and you change it because it's aging, it's old, you remove it, you put another multiplier, it's a bad one, and you know maybe after one day of work, you say – well this one is not good and you don't know why. And so I think that I would see improvements in that direction; there is room for improvement. I don't know if improvement will be made but there is room for improvement. And I think listening to what François told to me there is sometimes the same problem with the cesium source; you can find a very good cesium source, an excellent one, and it will last long and have good brightness and you have cesium sources that don't work well. But you know, the difficult thing here is it's just like with a match. Before you try the match, you don't know if it works; and this is here the same thing. Before you try the gun, the ion gun, before you try the multiplier, you don't know and it's really disturbing. You put a new multiplier and then you know that you may change it right away. You put a new source and you know it's not good so you lose time and you are very much upset by this situation. So I think that reliability on multipliers and sources is something I don't know how to achieve it but I know that there is really room for improvement in those parts. And also it might be interesting to explore other ways of using the instrument – nothing has been said about the relief of instrument – if you have a grain, for instance, like the work done by Frank on grains – the collection on grains; and so the point is that those instruments are, they are mainly operated by users, that means people who have a strong interest in some special problem like Claude on biological samples – and it's good I just describe the situation, or Frank with the meteor items and stellar dust particles. And they face problems that the instrument designer didn't face because they have no instrument to work on it and also I think that the situation for instrumentation is not so good – you have a few companies like Cameca doing work you may criticize – this is not good, it could be better, of course – you can always think it is better – but they exist and they do things and they propose instruments and people can use the instrument and can make excellent work with the instrument. Of course if we had, I don't know, at places like MIT or big universities, people working on instrumentation specifically probably we could reach much better – not much better – but somewhat better quality of instrument I think. The instrument François is talking about is the second prototype but we can, with the experience we have, imagine to rethink the optics; try to get something which is easy to adjust, to find better ways for adjustment and so. But to my knowledge there are little places in the world where people go on working on those problems and for the future I think it's a big problem because Cameca is very good, but I think they have not the power to invest a lot on instrumentation research. They can do what – like the cold stage – they can do it if a customer says, well I will buy it, so you buy it, they will engineer this and since they have not done, they will make mistakes, it will last some time. But if someone is coming with a view, a new idea that – and no funding because you don't know the outcome – then it will not be done. And maybe there are a few ideas lying in a drawer because it is too expensive; so if you can find the solution to that equation you will have better instruments. I am surprised that the semiconductor companies they are very, very demanding but they then put a cent in instrument research.