Soft Nano Technology
Prof. Rabibrata Mukherjee
Department of Chemical Engineering
Indian Institute of Technology, Kharagpur

Lecture - 26
Atomic Force Microscope – 3

Welcome back. We will continue our discussion on the Atomic Force Microscope. This is the third lecture on AFM.

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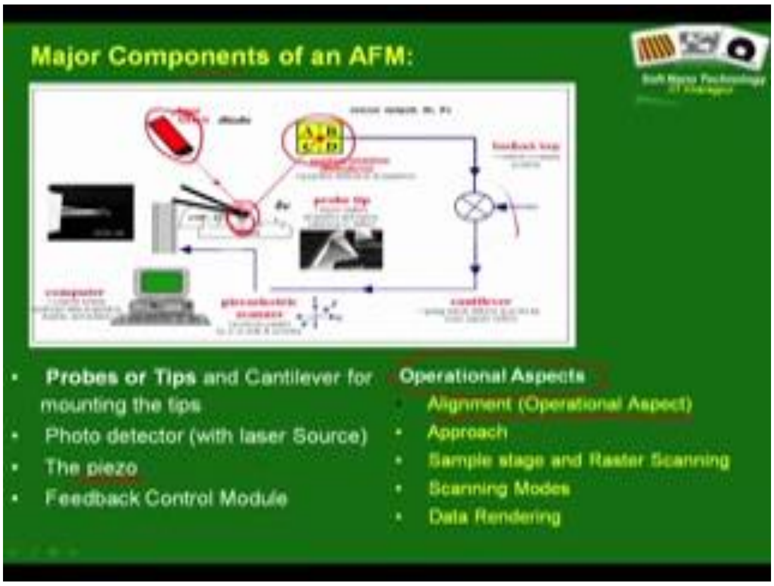

In the previous lecture towards the end of the lecture, we discussed about the different major components of an AFM. Which we are going too sought of a discussing somewhat greater detail and some critical operational aspect which will give you that even better idea about the working of an AFM. So, I will just recap on that of course, we have now understood that we need sharp loops, but unlike an STM, the probes are not stand alone and they have had to be mounted on a cantilever.

The purpose of which I just briefly mention that the purpose of this cantilever is essentially to track the variation of the interaction forces, but how it is actually or exactly done is a requires a little bit of more discussion which we will do. Then we have a photo detector with a laser source. In fact, you see the laser falls here it is some of it reflected. So, it seems the these 2 are optically couple though that tip of the cantilever and that is in fact, the situation, how to do that coupling is actually alignment that is an operational aspect that I will discuss. Then this tip is mounted on a Piezo scanner which scans and then of course, you have a feed back control module.

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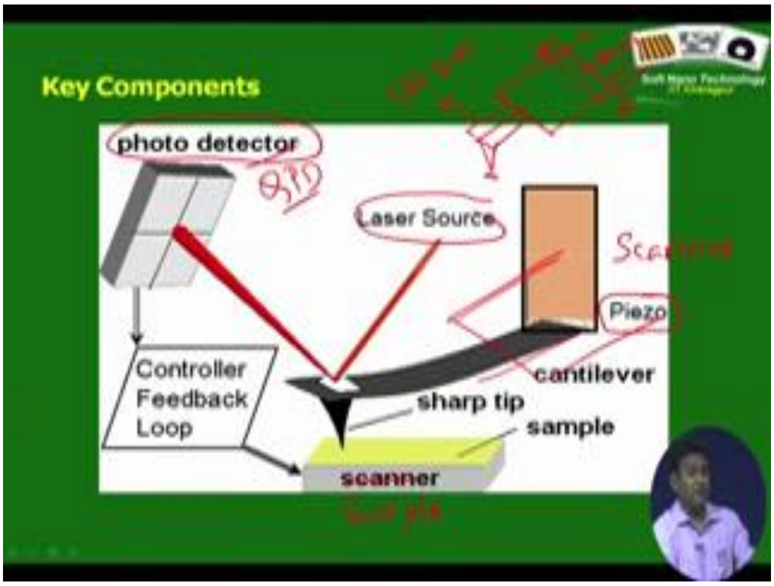

So, with introduction let us start the means this is another cartoon that is sought of gives you in somewhat greater detail the major component. So, you can see you can correlate to the previous slide; here is the Piezo scanner to which that cantilever of the tip is mounted. In reality it is not exactly so like this, were the cantilever is too small it is a may be a mille meter or 2 mille meters or may be even smaller than that few 100 micron. So, that is actual the geometry is this is the cantilever, it is mounted to the microscopic chip and this is about 5 or may be 10 centimetre 10 mille meter widen sorry and this is mounted on the AFM cantilever holder as it is called and this is very very small. So, this may be about 500 micron and this is tip diameter is the order of few times of nanometre at based.

So, any way for the major purpose, major reality there for our understanding we can assume that the cantilever is mounted to the Piezo scanner. Then you have this laser source and the photo detector. In fact, it is called a quadrant photo divot as will see soon QPD and you have a feedback controller and this is. In fact, this is the scanner, Piezo scanner, this is the sample, were earlier designs were the scanner other ratering X,Y ratering is to be done at the sub straight and Z control was done by the peizo mounting, Now the models include ceiling recall Piezo and everything is done roughly by the scanner.

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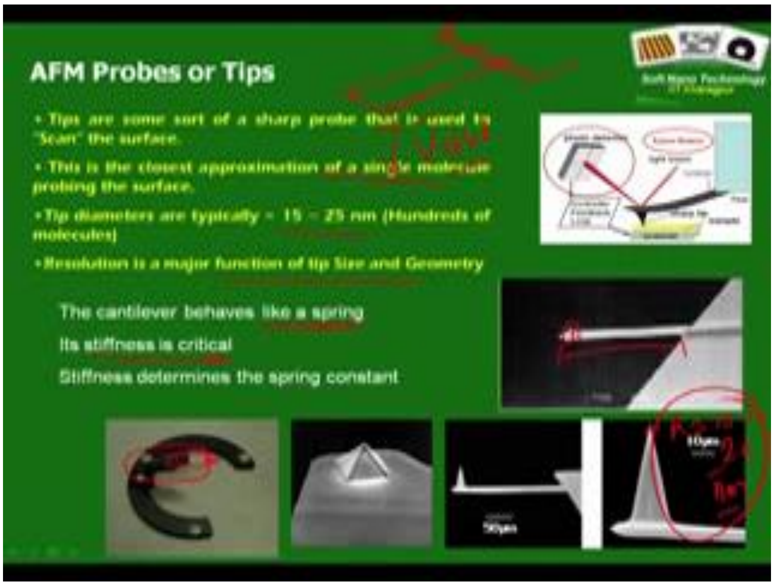

So, moving on the probes or tips the most important let you can see this is the real life SM image of what I told. So, this is the cantilever, this is typically made with silicon nitride or silicon, silicon nitride probes are very common. So, this is that every instrument it wearies. So, this is one of the probe mounts, here that so called chip will fit in like this and the cantilever will be like this. That is what you see this is the tip, in fact another the age of the tip is very short, this is a typically radios of curvature is 10 to 20 nanometre.

Again I will repeat I have briefly mentioned why you need a very short tip. It has nothing to do with the travelling current, like why the sharpness of an STM tip is required; however, if you take very bland tip please do not forget and you will soon realise that the minimum resolution you can achieve is strongly dependent by the radios of curvature of the tip right. So, if you have a bland tip your radios of you are later on resolution will decrease.

So, here are some details, tip diameter 15 to 25 nanometre, resolution 5 function of tip size. Cantilever behaves like a spring and. In fact, there is one more intermitted and contact of the typing mode and it is popularly called like this spring property is extensively utilised. Its stiffness is critical this also have mentioned because you like to take a cantilever that is flexible or mar able enough that it deforms handraval sports with the surface. You do not want any make it take a very rigid cantilever rigid as not deform because that does not serve of purpose.

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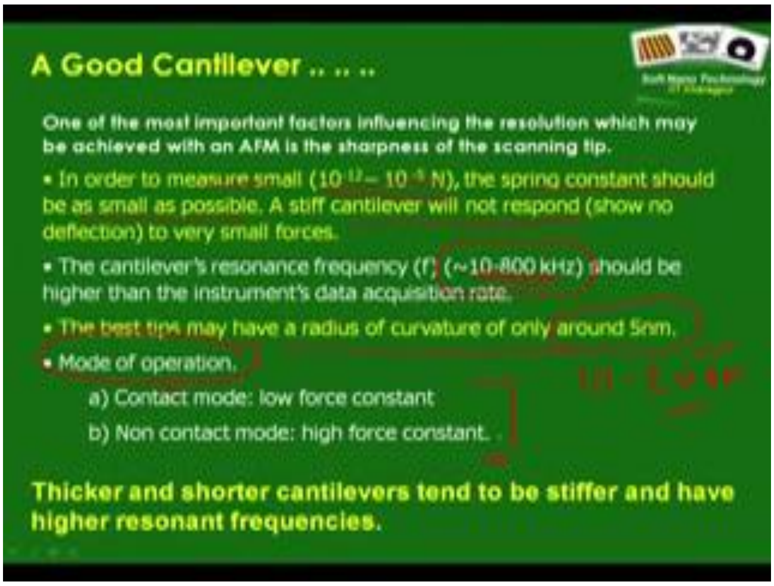

So good cantilever is a measure small, spring constant should be as small as possible, a stiff cantilever will not respond, resonance frequency this is important, it should be in this range. Resonance frequency you need in one of the most we will discuss the best tips have a radius of curvature of around 5 nanometre, but many of the commercial tips on uses have radius of curvature of 10 to 20 nanometre because these understand the fabricating tips.

So, with this small size itself is a major micro fabrication challenge and therefore, tips are very expensive and smaller or sharper radius of curvature at the tip edge you would like to more expensive your tips will be. Modes of operation we will discuss later, this is nothing to be big tip, but there are primarily two modes contact mode and non contact mode of the intermitted contact mode.

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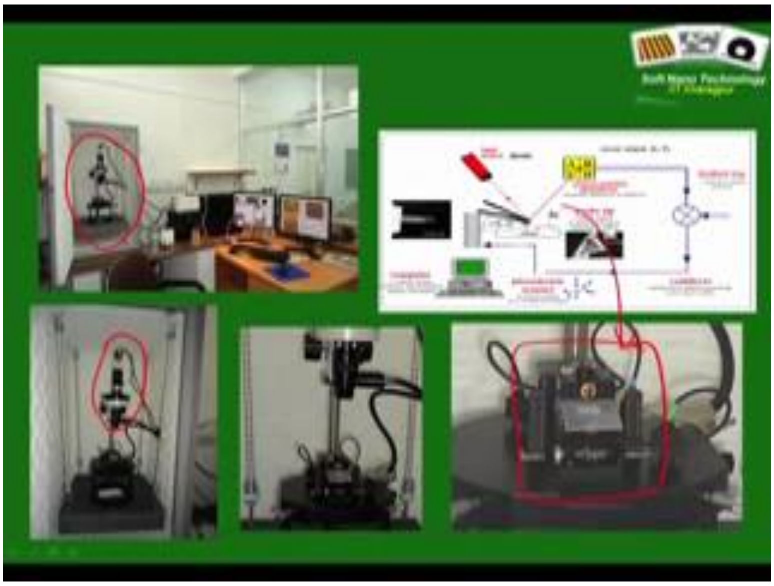

Anyway so these are some real life pictures of an AFM, but this again varies from instrument to instrument. You can to get a feeling that this is whether some microscope like thing is. In fact, it is an optical microscope; it is not related to the atomic force microscope. The real AFM is only this much is it is a small device in everything, but you see is sought of other then the controller is embedded in over here. That is again not a big deal.

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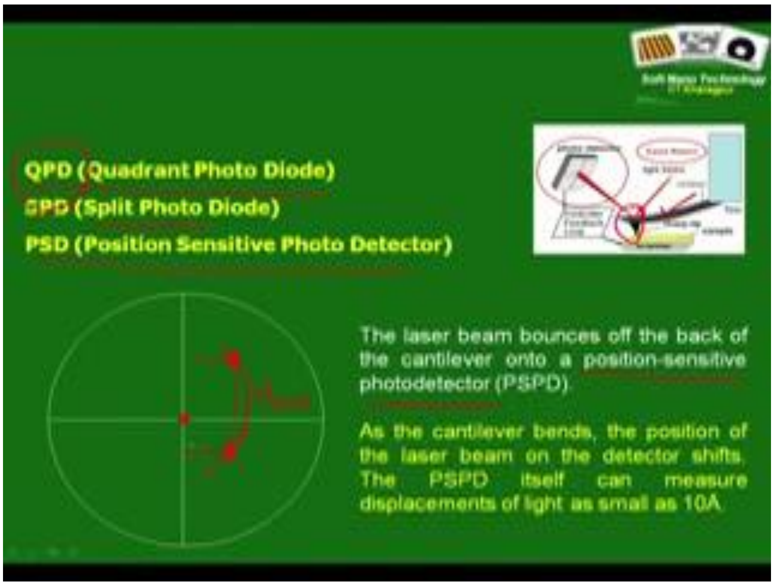

So we have already talked about the tip and the cantilever. Next we focus or attention in the so called photo detector of the photo diode. So, what we have? What is the photo diode? If you fall light, fine light on of diode, a type of diode over which if you shine light it will generate some voltage that. So, it is called photo diode.

So, what in a commercial area what is a used is not only photo diode, goes by the name position sensitive photo detector or often it is called the photo diode. So, what it means is that depending on the were the light falls magnitude of the voltage generated is going to different, typically the range is 0 10 millivolt and if light is shined at the centre it is 0 mille volt, if it is falls at the periphery 10 millivolt. However, more importantly even if that is a these 2 points follow on the same circle that is the total voltage is same, the position sensitive diode can sought of identify that difference in the position, that is the coordinate sequence that is why it is called quadrant photo diode, split photo diode, whatever PSD also position sensitive photo detector.

So, though let us put it like, both of this lines lie on the 4 millivolt lines are the X and Y coordinates here and here obliviously like a draft paper their going to be different and the QPD can identify that. It is good to know this thing, am I if you a really doing research on a atomic force microscope you can manure those things to achieve or extra more data even if you do not understand so much, it is good to know how it actually works. For our understanding this much is sought of enough. This QPD will be in fact used to track the displaced of the reflection of the cantilever as you can see here, but how we are we will talk about it in too many times.

What is important to realise that in the context of this QPD, it is able let set to track if the reflected light was initially falling here and after some reflection it has now shifted to this position. This is very important. In fact, if you remember our basic understanding of how an STM works. A scanning probe microscope always requires an error, particularly with the feedback loop.

So that the feedback loop can be activated at every point and you can get back to something that was set at the beginning of the scan that is the set point. What is the error? In case when you are trying to measure the forces and I am giving you the clue in fact the error is generated on the quadrant photo diode. What exactly is the error, you will soon understand once I talk about alignment and approach. So, this is the QPD.

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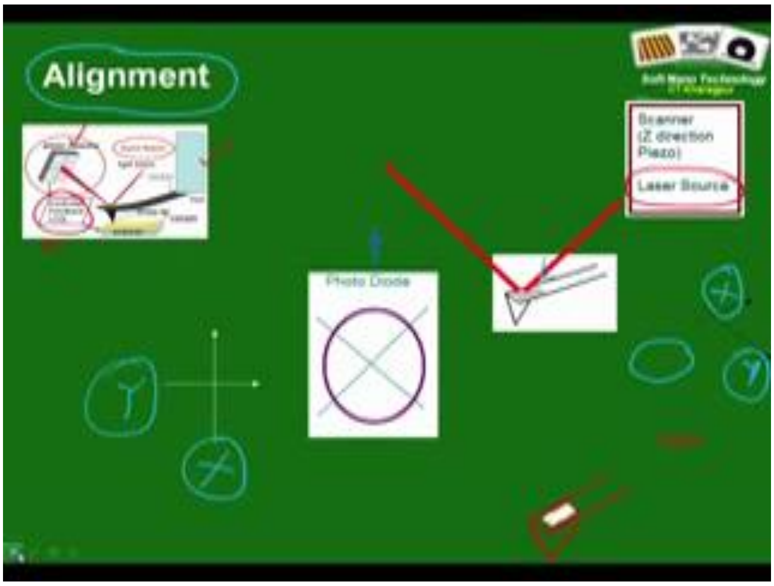

Now you see amongst all the instrument, major components we have not talk it about the Piezo, but you know that is a Piezo scanner, but see you know that we have already talk that a Piezo scanner Piezo electric material is something to which if you apply a voltage it can change it is dimension or if you forcibly change its dimension it will generate some voltage.

So here in fact we apply a voltage and that voltage how comes that voltage in fact comes from the feedback loop how that error voltage gets generated you will understand. So amongst these major components we have talked about the photo detector. Of course, there is the laser source; we have not talked about much about it. Feedback controller simply we will not talk much because just a fix the error and adjust the Piezo scanner. We will talk about the scanner shortly.

So, let see here we have that laser source from which laser light is coming and here we have the cantilever and the tip. Only one thing I briefly mentioned in one of the initial lecture, but I forgot to tell in detail, that this is the typical geometry of the cantilever, here it has a tip. Additionally on the reverse side of where the tip as made a shiny coating, reflective coating is given its not working. So, let me see what I can do sorry standing out to be black and let say.

So, over this area you have a shining coating. What is the purpose? Anything shining into reflects light that, yes. In fact, this X like a micro mirror. So, that is exactly what you see here, just one second, that is what you see here the cantilever sought of as grey coating this is in fact the surface coating.

So now, we are going to talk is the process of alignment and what alignment does is he will now realise that this in fact couples, optically couples the cantilever and the laser source and the QPD right. So this what he does? So, what you had? You had a cantilever mounting were you are a 2 screw, which you can rotate in X and Y direction that is all and you have this QPD which also come with two screw which you can rotate in again in X and Y direction. So, it is roughly like you have a like laser source coming from here right and you have a QPD somewhere over here, which you can move up and down and this particular plain and you have the cantilever some were over here I told the laser is falling from here which again you can move back and forth in this particular direction.

So, what you first do see the laser light is falling from the laser source, you have your cantilever first you have to mount your cantilever to the cantilever holder, then you start turning those screw this 2 screws the X and Y screws and in the process what you do is. So, this is the reflective coating we have already talked about and you are now turning and your object is laser light is going in this direction, light is simply going in this direction and your object is to somehow bring this cantilever into the part of the laser and this what you do. The movement of do that what is starts to happen since it as a shiny coating laser light starts to reflect out from the tip. It reflects from the location opposite of which the tip exists. Is it clear? I think I will sort of repeat this step.

So, you have this laser source, you have this tip mounted on the tip holder, then what you do, you in fact rotate this 2 screws the X and Y screw in such a way that the cantilever is shifted and it now lives in the optical part of the laser right and the movement it goes to the optical part of the laser since it has a reflective coating over the here the laser light gets reflected.

So in fact laser light, which was initially going in this direction as not go in that direction any more. This is only part of the alignment has been achieved. Now what is the next thing to do? The next thing to do is you again rotate the now you rotate the screws the X and Y screws of the photo diode, in such a way that you can move the photo diode and again bring it to the part of the reflected laser light. You want to bring the photo diode, so it is like this; laser light is now reflecting like this, we have the photo diode which might be Q.

So you do something you rotated in X and Y in such a way that it goes and the laser light falls at the centre of the photo diode. So that is exactly what you do here you sought a move this 2 screws and your controls are minimal. In fact, that is something you need to know that, you just have this X and Y screws you rotate it and the photo diode sought of those into the path of the reflected laser light.

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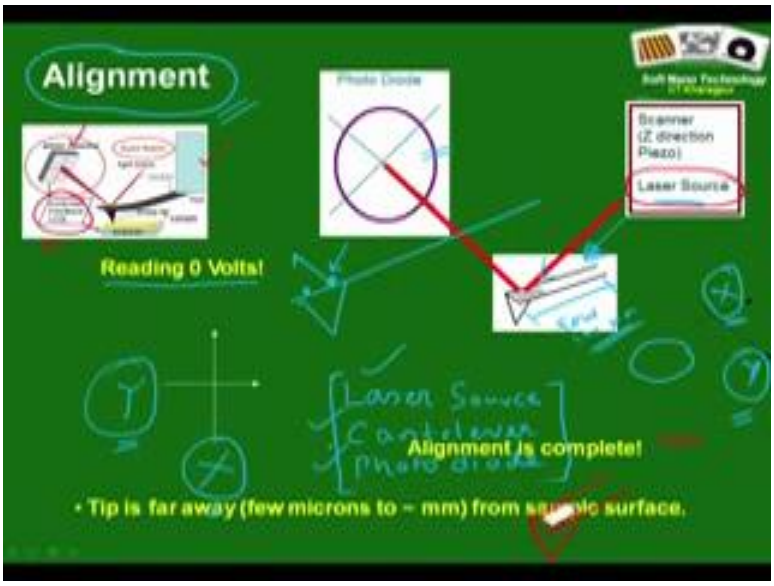

And you do it in such a way that it falls, the reflected light falls at the centre. What did I mention about light falling at the centre of the QPD, that would lead to a 0 voltage and this is one alignment is completed.

So, what have you done? In fact, you have now optically coupled the laser source and the photo diode, optically coupled the laser source, the cantilever and the photo diode. This process of coupling these 3 is called Alignment. This is I must admit that I am giving you a completely operator perspective, I mean if you want to really this is not really related to the science of an atomic force microscope, but if you want to on the AFM you need to know this things and I find it extremely interesting. Honestly speaking all you have at your disposal is 2 sets of screws, which have which allows you to move the cantilever as well as the photo diode along one particular plane and therefore, this step the process of alignment requires some beta of operator skill.

There are modern day instruments which does automatic alignment and many people tend to pay for those because trust me this is not the easiest of the thing. You are trying to bring in something in the path of a laser light which I will say at this entire portion is 500 micron. So, it is indeed small it is not that easy, but you talk to any experienced AFM operator or somebody who has been working with atomic force microscope for a significantly long period, he or she will immediately tell you that they will pay for manual alignment because that is where you really know.

Thus, if you are look very carefully, manual alignment really allows you to identify, weather your laser is falling here or it falling here and that effects image quality you ask me right. So, I have above 10 years of an hands on experience in may be more then that with that of atomic force microscope so with that I tell, but any way this is the process of alignment.

Once the AFM is aligned, in fact it is fine. So, reading is now 0 volt, which is and then we would have done all this but our anyway our objective is to scan the surface, but whatever I discuss so for that is alignment were these 3 components get coupled we have not talked about the surface A. So, what is the next step, now you sought of couple the surface with this assembly? So, that your AFM is ready to scan and this particular process is also very important it involves very easy, but very certain science and we will talk that in sought of detail is known as Approach. And that is what the next thing we are going to talk about.

So, what is approach? An approach in fact, realise fully on the concept of interaction of van ravel forces between 2 surfaces.

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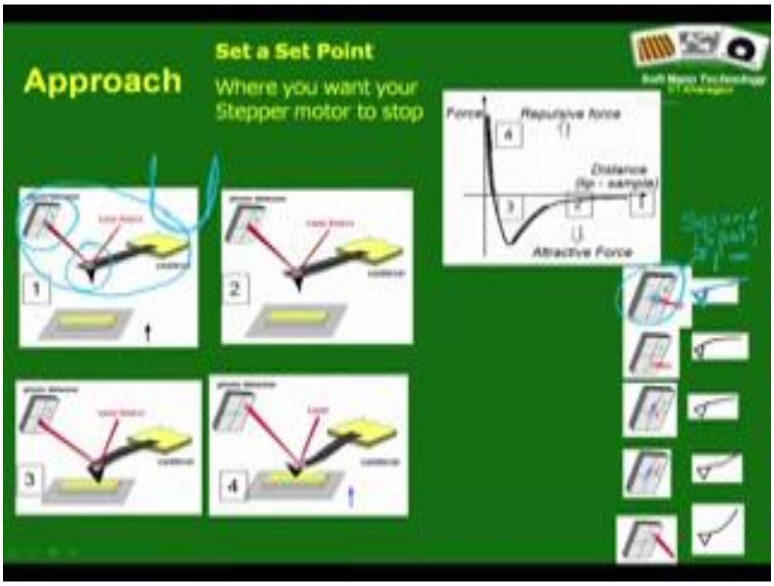

So, let see what it is. As I said that when you initially align the cantilever the surface is far for away right. T he surfaces no effect. In fact, you would like to align for away from the surface because you are moving the cantilever roughly with your hand then you do not want the cantilever to crash on the surface, that is why alignment is done far away from the surface, but now I would also like you to look carefully to this image and to look at 2 aspects, the laser light is falling at the centre which is something or you can look into here because this is getting truncated in some of the screens. This is the first configuration. Configuration 1, it is like this. What you know is that laser light is falling at the centre which is fine, but you see that I have given another tiny blue spot. Can anyone guess what is that spot? It will be clear to all of you very soon.

So, now what we do this. So, this cantilever is mounted to a there is a Piezo scanner and there is in fact a stepper motor which is now going to bring the surface close to the cantilever tip. So they come in contact and now the system instrument is ready to scan. Now question to ask is when you are engaging the stepper motor. How much does it bring? How close does it bring the surface? And that in fact is determined by the reflection of this cantilever itself.

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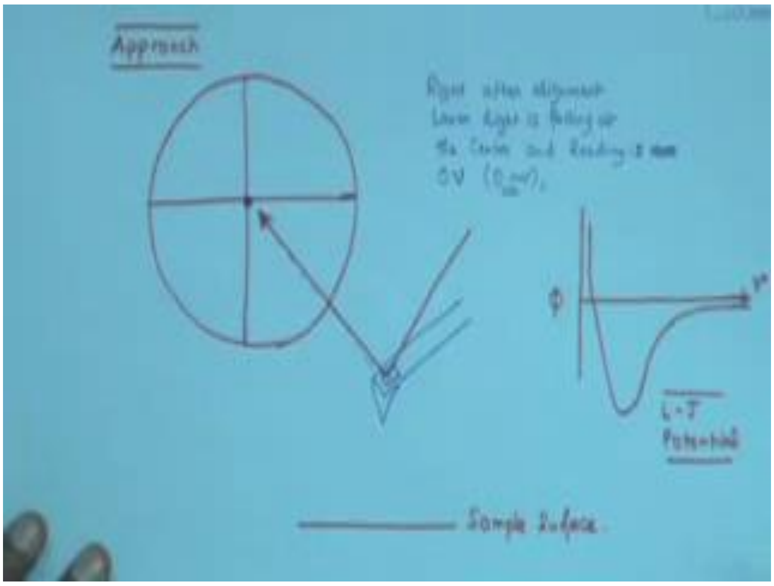

So, I will just draw or highlight this condition the QPD in big detail. So, all of you now understand that right after alignment, the laser light is falling at the centre sorry the picture is not very good, but right after alignment laser light is falling at the centre and reading is 0 is 0 volt or 0 millivolt. So, somewhere this is here is 0 cantilevers this is a tip. So, laser reflects laser is coming from the laser source gets reflected and it falls at the centre. So now, what is being done? So, initially when you do this alignment the surface sample was far away.

So there was no interaction and I would redraw something that we talk in greater detail in the initial class and should be able to identify it immediately now this is in fact the Lenance Johns Potential. I told you one thing and that is again I am going to tell you in one of the subsequent classes when I talk about in stability that Van Dar Waals interaction scales has 1 by to the power 6 between 2 particles fundamental particles, but when you talk about the interaction between 2 surfaces, it actually does not scale as 1 by to the power 6, it is scales as one by hour square, but if you look into.

So, AFM in fact you could see that we are talking about the interaction between the tip and a surface. The tip is sharp, but still the radius of curvature of the tip is 10 to 20 nanometre. Typical size of a in organic molecule is allowed an angstroms. So, considering that the tip as about 100 to 500 of molecule.

So, one way of considering that well the tip is also a surface. So, one can looking to the interaction as the interaction between 2 surfaces, but let me also tell you many people consider the interaction between the tip and surface to be governed by the pearl potential that is one by the power 6. Anyway the nature of the interaction remains same and probably it is the fact that it is it the scaling is more than 1 by the power 6.

So, and running that out of time so I think in the next class I will talk about the issues related to approach in greater detail. So, approach essentially is a bringing the sample in proximity with the tip. So, that your AFM is now ready to scan and most of the instruments excepting few. In fact, have an interlock that as long as the AFM tip as not approach the sample surface the Piezo scanner will not get activated.

So, this approach is not governed by Piezo because you actually you would like to gap bridge a reasonably large gap between this configuration let us say where you have done your alignment and your surface. In fact is possible and many times you actually do that. You first align your cantilever; align your instrument than only you mount your sample that is also possible.

So, the sample the rule of the thumb is that you align when the sample is not there because you do not want to have any spurious reflection coming from the sample and then once the instrument is fully aligned. Then you engage your sample and then you bring it close to close to it and that process of bringing the sample close to the AFM tip is known as approach. And I will pick up the discussion from approach in the next lecture.

Thank you.