Instability and Patterning of Thin Polymer Films
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Lecture No # 23
Atomic Force Microscope – II

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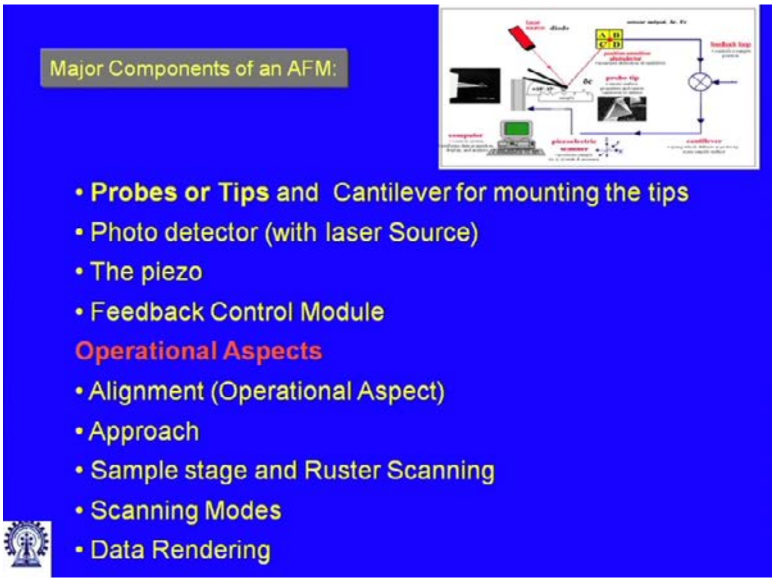

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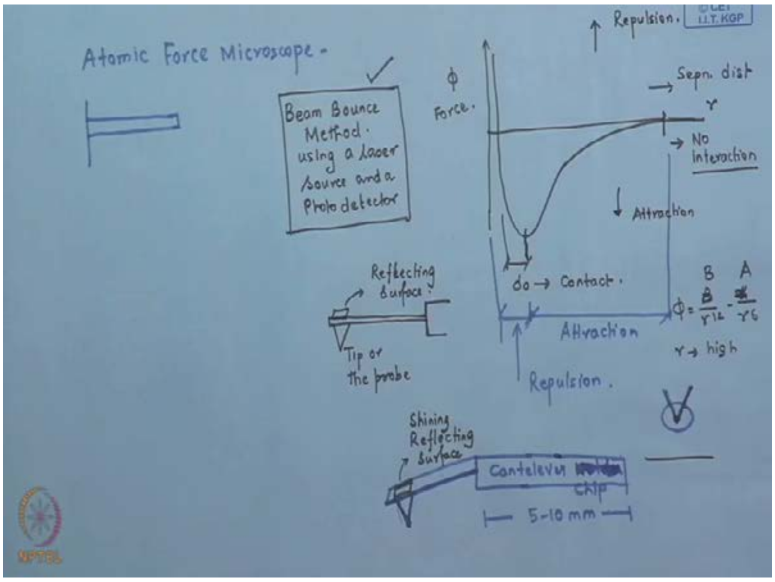

Welcome back, we pick up discussion again on atomic force microscope which we introduce started in our previous session or class. So, we have just talked about the basic features of atomic force microscope and introduce you to the concept of intermolecular and inter atomic forces primarily the Van der Waals forces which essentially is responsible for imaging using an a f m. And we also talked about the predecessor to atomic force microscope which is the scanning tunneling microscope are as the s t m as it is known. Now, in this class we will introduce you to some more hardware components often a f m as well as some fundamental, but very important operational aspects of how there how a f m works and what I will take for granted is that you are now well conversant with the potential curve which we talk in the previous class which is of this form.

So, it can be simply 612 potential or if you are talking about to surfaces about it can be attraction can be 1 by r square in the repulsion can be little shorter range. So, we understand this curve, this is the separation distance or r, this is the potential of the force, let us say this is a potential, does not really matter. Negative attraction is we will argue that to be negative, this is repulsion and you also understand this point, this is the point where the 2 surfaces come in contact and beyond this. So, up to this. So, beyond this, firstly, there is no interaction by the say no interaction we understand the there is the no interaction due to the inter the molecular level or particle level or the atomic level interaction.

So, the Van der Waal's prevence interaction, there is no interaction because if you talk about a simple I think we use b and a. So, let us use that to avoid confusion. For higher values of are both the terms tense to 0 and therefore, interaction is 0. Of course let us talk, we also argued in the morning that when we talk about the interaction in actually a f m they interaction is not between 2 fundamental particles or 2 molecules or atoms, but it is interaction between 2 surfaces. So, if we can convent this interaction between 2 particles into 2 surfaces by integrating it 4 times which we will see 1 of the subsequent lectures what happen is the d k becomes little more sluggish.

So, this r to the power minus 6 attraction gets replaced by r to the power minus 2 attraction and similarly that repulsion also does remain r to the power of 12 becomes something like r to the power 8, but the overall nature remains the roughly the same there is. So, for higher r there is no interaction shat so ever. Then we have significant range over which you have an attractive interaction and then beyond this zone you have repulsion.

So, you will I will assume that you understand the origin of geneses of this particular curves and based on that we are going to discuss. So, here are some of the critical components. Firstly, the probes or the tips we already have seen a tip like this which an a f m tip which is different from a s t m tip and this tip is often mounted to a cantilever. So, we actually have 2 components, 1 is the tip itself which is very very sharp here coming to the material of construction and things like that and it is mounted to a cantilever. Now, we all understand what exactly is a cantilever. So, it can be microscopic entity also, let us say beam which is fixed at 1 and fear the other end. These are micro on mini cantilever.

So, this overall length can be a few mille meter or smaller then that may be and so you essentially have a this is sort of attached to a cantilever holder, which is cantilever chip as it is called not the holder more of a chip, metallic chip which as dimension. So, we have to understand this is 5 to 10 mille meter and this is this particular chip is mounted to the a f m cantilever holders. So, we have to understand how small a thing we are dealing with. So, this is a cantilever and to 1 edge of the cantilever close to the very close to the age of the cantilever, the tip is mounted. Now, both the cantilever as well as the tip as some desire properties and you will talk about some of them. 1 additional thing before I forget let get me I highlight the typically in commercial cantilevers the deduction technique that is used is in the previous class we just mentioned about the method beam bounce technique using a laser and photo detector, we will come to each 1 of this elements for they do. So, in order to facilitate the use of this beam bounce technique with this laser source typically the this area of the cantilever has a shining surface are a shining reflecting surface.

Grossly, the zone which is opposite which is on the cantilever, but on the other side of other side of the cantilever to which the probe of the tip is mounted so, that means, just try it again more of an engineering drawing. So, this is the cantilever, here its mounted attach to the cantilever chip on 1 side, on the other side on 1 side you have the probe, the tip of the probe and on the other side you have small area which offers a reflecting surface.

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So, this is what is a cantilever and the tip we will re visited, then the other components we have a photo detector with a laser source which you have already talked here because most commercial a f m use a use the so called beam bounce technique for deduction or the deduction of the level of forces of the deflection of the cantilever. We have a piezo element, there can be depending on the module we can have 1 or 3 piezo elements. I understand, I hope you understand what is a piezoelectric material, its very simply put its special class of material across which if you apply a voltage it changes its dimension.

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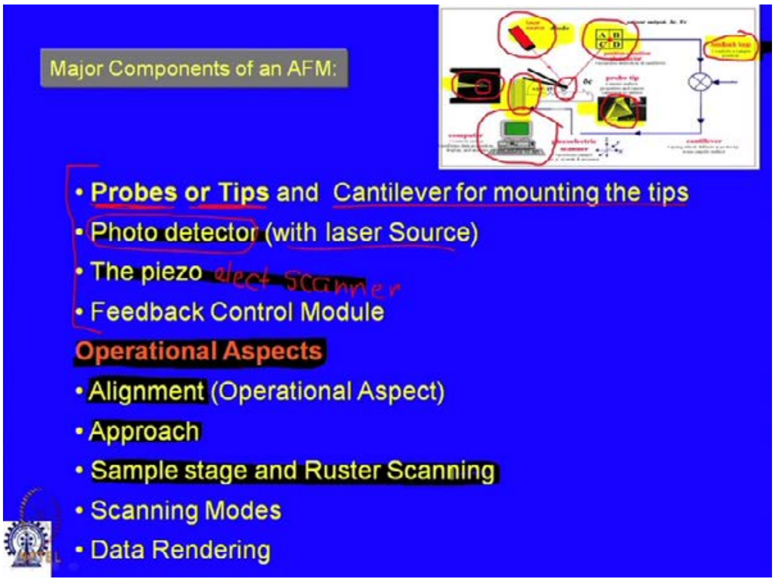

On a other words if you can change the dimension of piezoelectric material they a voltage sort of gets generated. Here, we typically use it in the first mode that is we apply a voltage which corresponds to the error voltage and based on that piezoelectric material changes its dimension how it works or where this voltage comes we will discuss, but you may just recall that in the context of s t m, we talked about the constant current mode and we talk that there exists a feedback mechanism which generates say difference or error voltage. A similarly feedback mechanism also exists in case of an atomic forces microscope and the voltage the error voltages fed to the piezo through this feedback loop. We will talk about it. So, the fourth hardware element is actually the feedback control module.

So, these are the grossly the hardware control element, this particular figure if you look carefully you will find the existence of some of this let my see if I have this image somewhere, No, I do not have it, sorry. So, some of these components we can already see for example, here you can see the prober, the tip that is mounted, here is the probe or the tip it is little smaller image, but we will show you a bigger 1, do not worry. Here, you can see the photo detector. The second element we talk about is a photo detector. So, here is the photo detector along with the laser source. So, here is the laser source you can see.

I can assure that once we have this class and probably the next class we will be able to understand the exact mechanism how it works, do not worry about it. I am just write give you an idea about how each 1 of these elements are presents. So, here you have the piezo the piezoelectric scanner maybe we should write piezoelectric scanner, not the piezo. So, is piezoelectric scanner now and here is you see the feedback loop. Of course, the operation of any (( )) instrument is of through interfacing with a computer show. So, you have a computer interface which runs the whole show. So, that is not exactly hardware of the a f m that is why I have a not included it, but here also whatever little thing you have discussed you can see that this particular picture is nothing, but that of a cantilever and towards the edge we have a tip which is mounted to it which is sort of shown in this blown up image over here. So, this is roughly a tip.

So, this is grossly the hardware elements we are talking about. The typically commercial a f m comes with. So, let me just quickly repeat the probes on that on the tips along with the cantilever for mounting of the tips. So, here is you can see the tip and. So, here is a tip and the cantilever which is used for mounting of the tip, then you have the photo detector. So, here is you have the photo detector along with the laser source.

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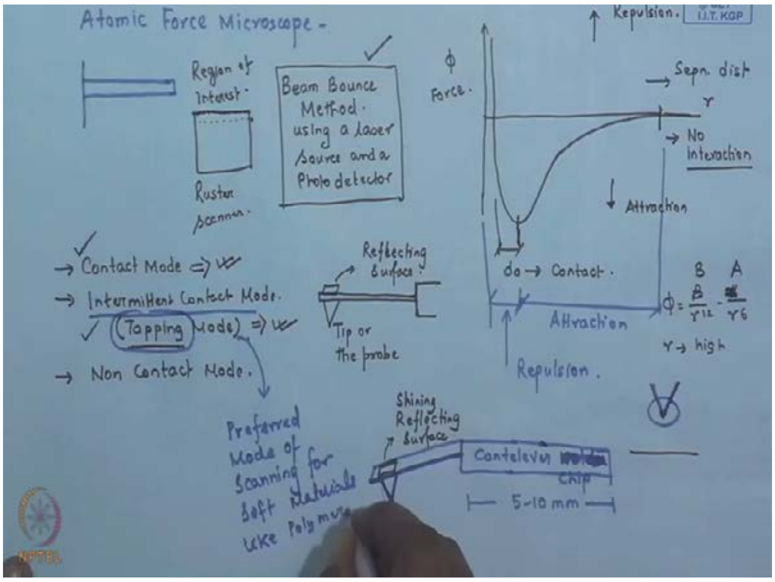

And then you have the piezo electric scanner which is here, how it works and all that we will discuss it in greater detail. So, here is the piezoelectric scanner and here is the feedback loop. So, these are grossly the 4 major hard work components, we will discuss them 1 by 1. Then there are certain operational aspects which I would like to highlight which is not a very common thing we will find a book, but if you sort of try to work with a f m its always important to understand these procedures because this gives your very clear idea about how an a f m works. So, the first 1 is what is known as alignment, second 1 is known as the approach, third one is more of any inbuilt thing that come the instruments, but you need to understand how it works its sample stage and ruster scanning.

While talking about s t m we have already talked about the ruseringt motion that is the scanner sort of identifies a zone, most of the cases it is a square zone and then its visits at every location point by point. So, let us say divide it in to 512 by 512 number of re points and there is an essentially a next a do loop. So, for j equal to 1 to 512 and then within that 5 equal to 1 to 512. So, the scanner starts from here i equal to 1, 2, 3. 4, 5, 6 all way the up to 512, then 512 to 1 it comes back for j equal to 1, then it changes to j equals to 2, then again for i equal to 1 to 512 goes all the way, then again comes back, goes like that. So, essentially this is what is known as the rustering action or the ruster scan.

So, the scanner of the scanner tip of the probe tip in case of a f m sort of visits at every location of the sample surface which is the region of interest 1 can say to collect the information about the topography or any other detail we are looking for. Then finally, of course, we talk about the scanning modes which is very important and we will discuss in greater detail the operating principle of 2 of the modes and they are the contact mode, the simplest 1 and the intermittent contact mode which is more wildly known or is more popular as the tapping mode, but please understand the tapping mode is a word you should not use scientifically because this is some sort of a trade name of this intermitted contact mode of a particular company, but somehow tapping mode is the word that is very popular.

So, most people working on intermitted contact mode they we will just tell you that they have done this scan in tapping mode and you can find this word tapping mode even in journal publication, some books and things like that. So, no hum you can either called intermitted contact mode are the tapping mode, then you have additional modes also the non contact mode.

We will discuss and we will see that as a stand alone mode this is not really that exciting because it is sort of offers poor resolution and the data quality it is not very good, but this based on non contact mode and by some additional features 1 can really generate a host of a information for example, current sensing a f m, magnetic force microscopy, all this very advanced methodologies which is essentially try to give you the different charge domains on the surface or different magnetic domains on the surface in addition to the topography they require in the classical form the use of non contact mode in a substrative fashion with a contact mode scan or a tapping mode scan.

Most of the cases this type of modes operate with based on the fact that you do 1 contact mode scan and then 1 inter non contact mode scan. So, that was the utility of non contact mode also comes in, but to understand the instruments we will first understand in greater detail how the contact mode works and we will follow it up with intermitted contact of tapping mode because as you will see from our discussion this is the preferred mode of scanning for soft materials like polymers, materials like polymers.

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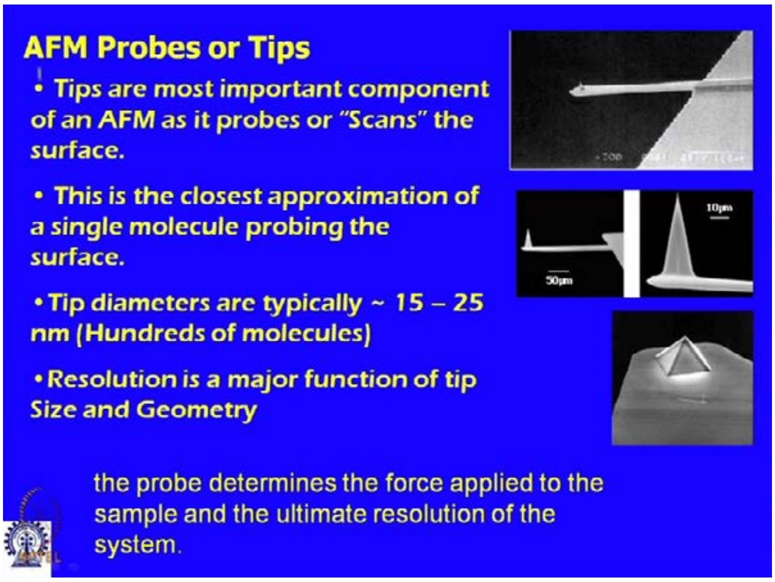

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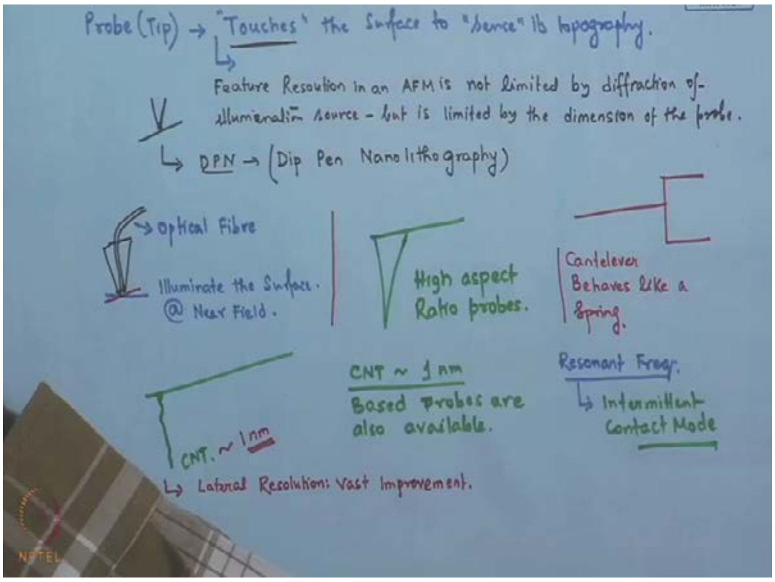

So, let us move on to the first thing we would like to discuss the probes are tip along with the cantilever for mounting of the tips. So, a f m probes are tips. Tips are most important component of an a f m as it probes or scan the surface. So, this is the element, the hardware element that acutely goes and physically touches the surface. So, the most. So, this is what the importance of the probe tip lies, this is the 1 that touches the surface to sense its topography and therefore, to a large extended information about the surface you acquire from a f m depends on the geometry or the condition of the probe. So, if you are using a probe which is not very sharp it will lead to a loss of resolution because you must understand the resolution here, the feature resolution is not limited by diffraction of illumination source, but is limited by the dimension of the probe.

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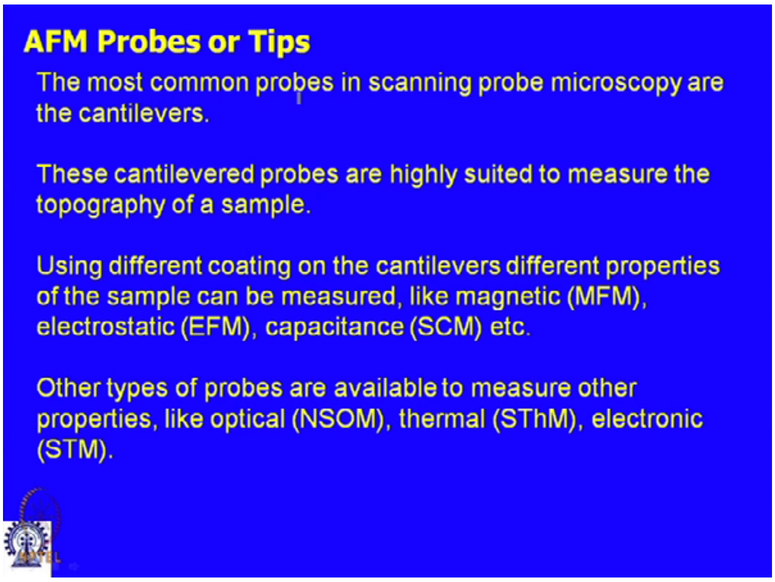

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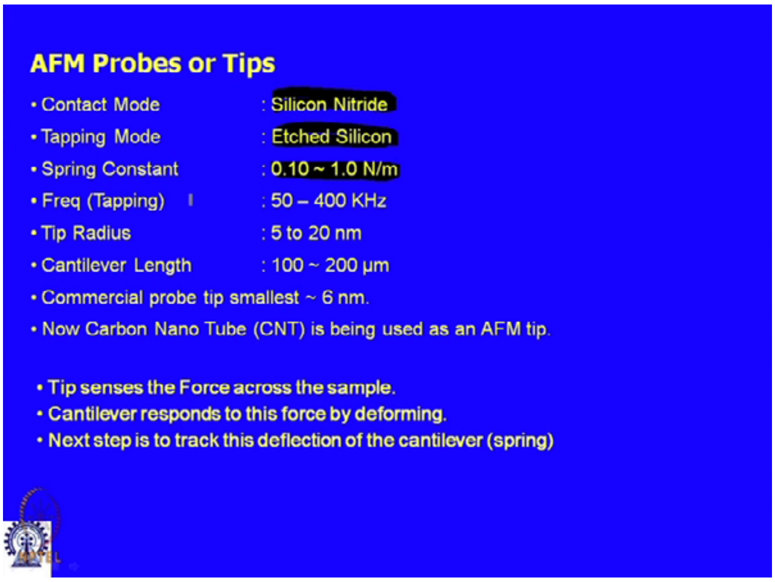

So, final is the probe geometry or the sharper is the probe better would be the resolution. Since, also we will also realize how it touches and all that, but let my just add a point since the probe physically touches the surface therefore, in addition to visualizing the surface feature topography like any ordinary any other microscope, it also becomes possible to do manipulation at the surface using and a f m platform and a f m probe because ultimately this probe is going to go and touch the surface. So, you can sort of dislodge some material using this probe, make an intend on the surface, or you can deposited sudden materials through this probe as it touches. So, this is like an additional advantage that 1 can acquire or 1 has while working with atomic force microscope because in all other microscopes including scan electronic microscope or an optical microscope you are actually getting a virtual image at the focal plane at the focus plane or the image plane due to illumination through light or electron wave whatever it is, but there is no mechanism by which there is anything that is physically going and touching the surface which is uniquely unique to atomic force microscope and 1 can harvest this advantage to a large extent by doing a lot of manipulations or lot of additional things at the surface using this probe.

As a example I will take up I will give you an example of what is known as Dip Pen Nano lithography towards and of our discussion on atomic force microscope which essentially is a nice pattern technique which uses the using the a f m platform, tip diameter typically in 15 to 25 nano meter which as I told we have talked in the previous class itself that they are roughly of the order of hundreds of molecules, resolution is a major faction of tips size in geometry, the probe determines the force, the probe also determines the force that is apply to the sample and therefore, the ultimate resolution of the system. Then the probes are in most cases mounted to a cantilever.

This cantilever probes are highly suited to measure the topography of a sample and with different types of coatings and different properties like magnetic force microscopy, electrostatic property, capacitance etcetera can also be measured, but there can other types of probes which are available for example, glass probe for example, or you can sort of have a probe trough which a optical fiber can be inserted to illuminate the surface. So, here is a probe and then it is sort of a hello probe and 1 can sort of have an optical fiber which can be used to illuminate the surface at near field and therefore, 1 can obtain near field image of the surface.

So, this that can optically image which goes by the property of NSOM which is known as the near fields scanning optical microscope. So, you can illuminate the surface at the near field there by you sort by overcome the diffraction limitations and can take an optical image, but again that is possible using the atomic force microscope platform. So, probes are tips typically material of construction offer contact mode it is silicon nitrate, for trapping mode probes are mostly made of acts silicon, the spin constant is within typically with in this range spin constant essentially the cantilever here behaves as a spring. So, this is the spring constant we are talking about. Why this spring consistent is important we will soon see then the naturally frequency. So, the moment you have a spring you are likely to have a resonant frequency which lines in typically in this range 50 to 400 kilo hertz. How, this naturally frequency or resonant frequency.

We will use what resonant frequency. This is utilized in large way in tapping mode and intermittent and contact mode. Tip radius we have already talked. It is roughly of the order of 5 to 20 nano meter. So, we are essentially talking about this radius. So, radius is 5 to 20 nano meter and the cantilever length, well I said it is few millimeter it is wrong, it is roughly of the order of 100 to 200 micron, the cantilever chip can be 5 to 10 millimeter which is actually put on to the cantilever holder.

Commercial probe tip is down to 6 nano meter diameter has is available is possible if you want to have scan some very deeps structures 1 can in principle have highest aspect ratio probes. Recently, carbon nano tube diameter is of the order of 1 nano meter slightly higher or lower based tips are also available now.

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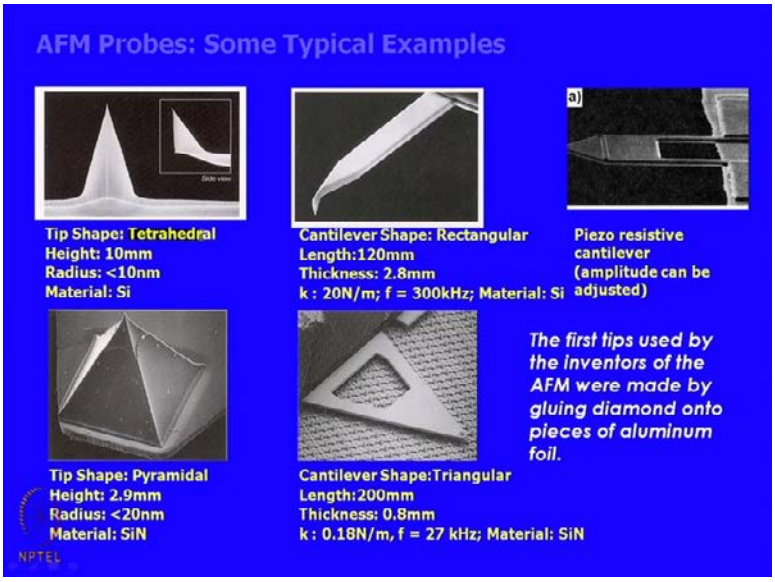

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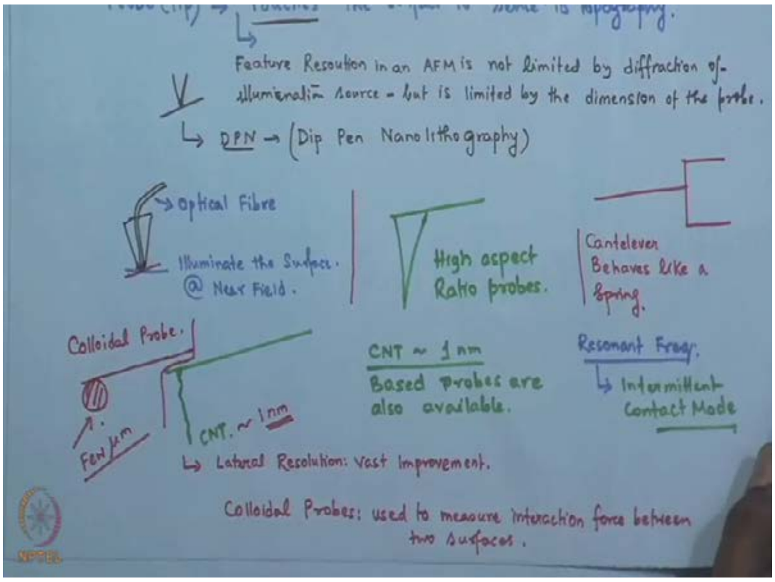

So, 1 has the cantilever and instead of the at silicon of the silicon nitride probe it is attach to 1 single carbon nano tube. This also this is very decent product which is coming for the last 2 to 3 years I guess and since the carbon nano tube diameter of close to 1 nano meter first likely less than the this result in huge improvement in the lateral resolution, vast improvement in the lateral resolution. So, this is tips senses the forces across the sample, cantilever response to the force by deforming and the next step is to track the deflection of the cantilever or the spring.

So, what it means we will understand in simple works, but let us have a quick look into some of the a f m probes. So, this can be tetrahedral probe you can see the height 10 nano meter, radius is less than 10 nano meter, material is silicon, you can have rectangular tips, you can have piezo resistive cantilever, you can have triangular shape cantilever, you can have pyramidal tips things like that. It might be interesting to know the first tips used by the inventors were made by gluing diamond onto piece of aluminum foil. So, this is the first tips that were used and it has. So, tip making itself is a significant business and there are dedicated companies who make this tips because you need to h them to perfection to have the desire geometry and the sharpness and the radius curvature.

There can be some additional thing is also available which are known as the colloidal probe or colloidal tips. So, instead of a, on the on to the cantilever instead of a, instead of a. So, here is the cantilever and 1 typically attaches a colloidal particle to this probe. So, this type of probes this has a pretty larger diameter. So, it can be few micron and what is interesting to note is this type of probes are not used for imaging because you can understand that which such a probe with a secular cross section the image quality will be verybad, but this type of a probe or tip is very routinely used for measuring the force of the interaction forces between 2 surfaces. So, colloidal probes interaction force between 2 surfaces which is another of offshoot of the a m f probe going and touching the surface 1 can measure the force of interaction between 2 surfaces using a atomic forces microscope.

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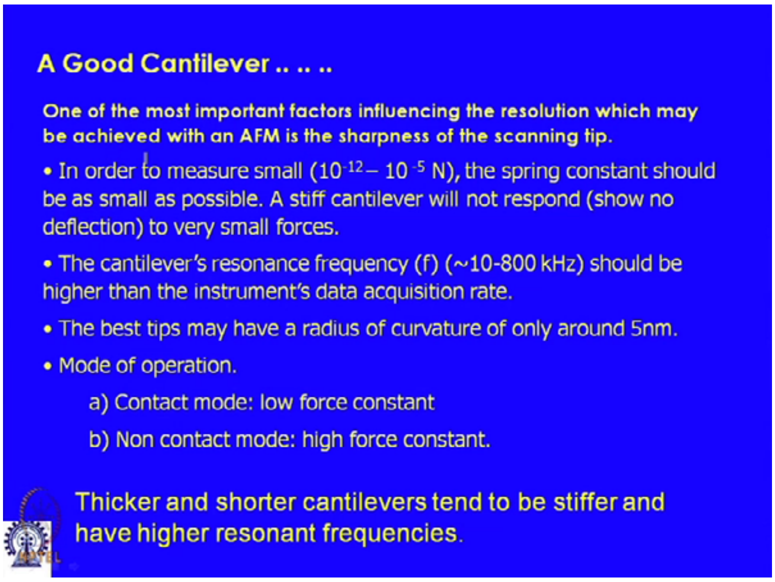

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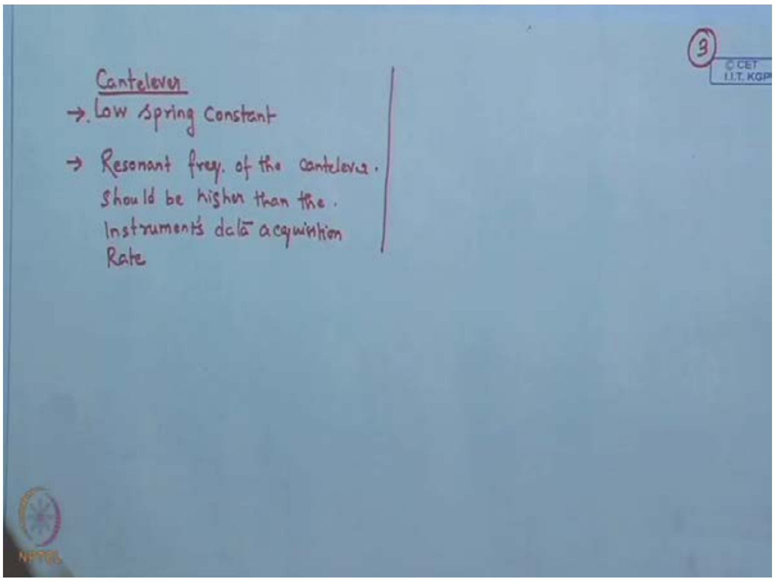

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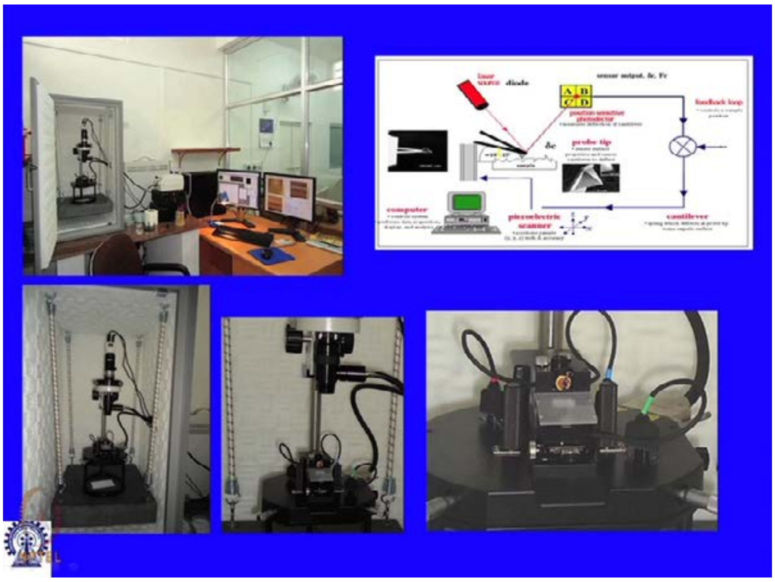

So, this can be used to measure the force of adhesion between 2 surfaces of similar or dissimilar materials. Now, a good cantilever has a, must have a few properties. So, firstly the thing is in order to measure small forces the spring constant should be as small as possible, a stiff cantilever will not respond to the very small forces or deflection. The, we will discuss what it means. So, the spring constant should be, the first criteria is the that the low spring constant, second things is the cantilever resonant frequency should be higher than the instruments data acquisition rate. This is extremely important that, we must have the resonant frequency which must be higher than the data acquisition rate of the instrument otherwise there will be mix up and you will get the appropriate data. This is a.

So, with that you can, here you can see the same figure again. So, this is the schematic of a f m with the hardware elements we have talked about already, tip and probe, the piezoelectric scanner, the photo detector and the laser source and the feedback look this is how a commercial a f m looks like. So, this is all interfacing and computer. These are the controls what you can see over here. This is a typically a f m, actually the a f m sits over here. It is smallest, this 1, this is actually the a f m part of it, this is optical microscope which often is mounted to a a f m a low and optical microscope resolution just you see that your tip has been attached properly or something like that.

Before, I move on to the other hardware elements of the colloidal photo diode, let me just explain to you what these 3 sentence mean that the tip senses the force across the sample, the cantilever response to this force by deforming and next step is to track the deflection of the cantilever. So, what it means now you understand that you have a probe which is a very sharp tip which is mounted to a cantilever.

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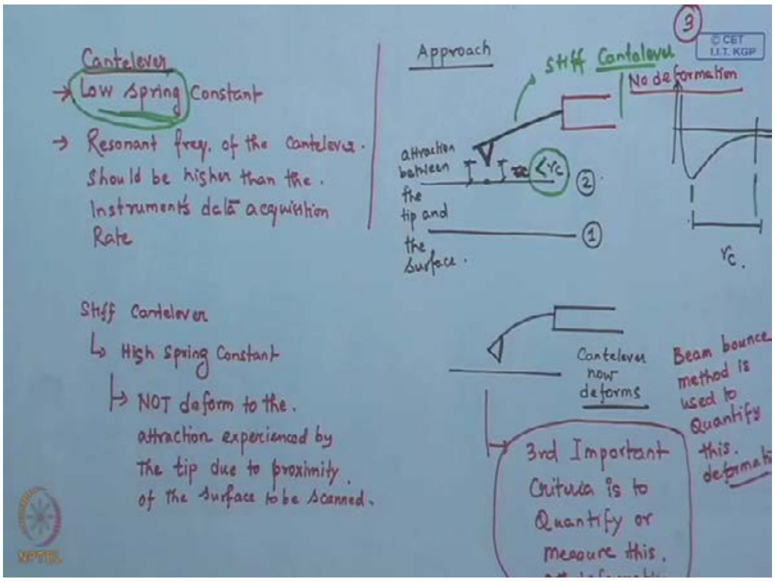

Which acts as a spring. Now, what is done in an a f m you will understand the this is we have already mentioned about this particular technique what goes by the name of approach, it is as follows. We will discuss approach again later, but what is done suppose you want to scan a surface or want to investigate a surface. So, first you do this the a f m tip is far away from the surface and so there is no deflection in the cantilever. Now, what is done slowly before you start scanning the surface is brought in close proximity or first brought in contact with the cantilever tip, it can be either around you can also have instruments in which the cantilever is progressively brought in contact with this surface. Now, what happen is I would like you to now remember this curve again.

So, when these 2 far away you are some over here, there is no interaction between the 2 surfaces and what are the surfaces here? The surfaces here are the tip of the cantilever and the surface you want to scan. Now, as you bring it closer, how you bring it closer, where to stop we will discuss subsequently, but I am just try to give you a glimpse of what we mean by these sentences, the tip senses the force and the cantilever responds to this force. So, as you bring this let us say you are moving this surface up closer to the cantilever what happens is when the separation distance sort of becomes smaller than this limit. So, whatever that limit is let us say or see. So, when it is a adequately close and these 2 are smaller then or c what happens?

Now, you are in a regime where there is attractive interaction between these 2 surfaces, that is this surface and this surface. So, if the tip is, if the cantilever is adequately flexible that is the spring constant is low enough to, low enough to what extent? To the extent that it can sense or it deforms to these type of forces, forces in this range. So, then what will happen what will happen. So, this was the first location, now let us say you have take it closer to that what will happen is because of the inter surface attraction the cantilever will deform. So, this is the mechanism there is a attraction now between tip and the surface and because of that because of that attraction, the tip now, the cantilever now deforms. So, this is what is first meant by the tip senses the force across the sample.

So, as you bring it closer and as the separation distance between the tip and the surface falls below this limit. Now, the tip sort of starts feeling the attraction of the surface. This attraction is p only Van der Waals interaction what we are talking about. The attractive part of Van der Waal's interaction, there is no conductivity involved like what is necessary in a s t m, there is no surface charges are associated. So, irrespective of whatever is the type of the surface these attraction will always be there. What you have to understand this separation distance is now very very small. So, you cant do it manually because we have the risk of break in the cantilever tip.

So, these are all motorized. We will talk about it and this is what you have discussing is part of the process of approach, but once it is less than this critical separation distance. Now, there is attraction between the tip and the surface and your cantilever should be such that it deforms to these type of attractions, this level of attraction. So, 1 has to understand that we have talked about the fact that inter molecular, this type of interaction the magnitude of the forces are of the order of 10 to the power of minus 5 to 10 to the power of minus 12 Newton. So, these forces are very small.

Now, if you take a very stiff cantilever let us say we high spring constant, what it will do? It will simply ignore this force. So, there might be an attraction between the tip and the surface, but if you are cantilever is very stiff it will not deform at all. So, there might be attraction, but there we will be no deformation.

So, this is a scenario what will happen if you have very stiff cantilever. It will not deform to the attraction or attractive forces are experienced by the tip due to proximity of the surface to be scanned therefore, it becomes extremely important to have a cantilever that has the appropriate spring constant. So, that it deforms to these attraction forces. Next, what is important is that it deforms and what exactly it happens do we sort of scan and this configuration or some other configuration that is fine, but what needs to be done the third important thing is to quantify or measure this attraction this deformation.

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And it is the beam bounce method is used to quantify this deformation. So, we will talk about it, but I guess this gives you an idea about why the required property, there are certain specific requirement there on the cantilever you are using and 1 of them is the low spring constant. We will initially talk about the taping mode imaging in which the resonant frequency does not really come in to play. What is the exact role of the resonant frequency because if you remember carefully there was also a limit or a condition set on the resonant frequency which is specific to the tapping mode. The spin constant, now I hope you understand why you need to have cantilever with a low spin constant in this particular range.

Of course, you understand already why you need to have a very small tip radius because to a large extent the resolution of a final image is a function of your tip radius.

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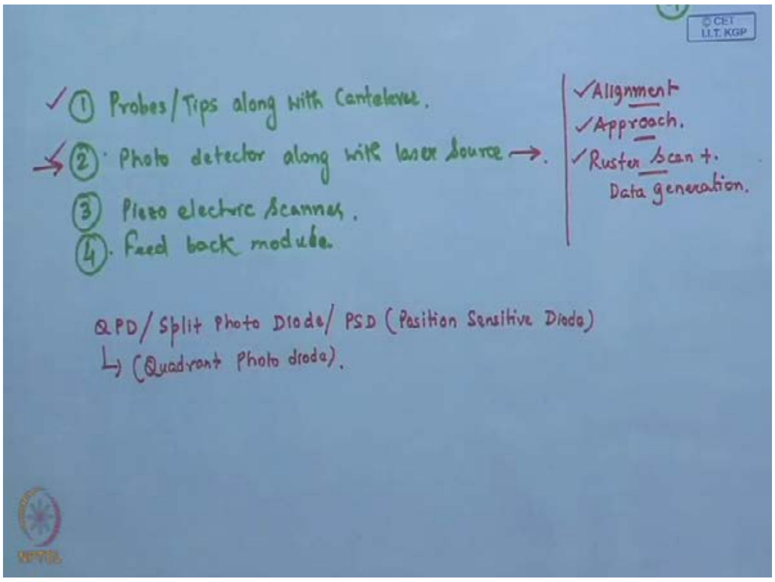

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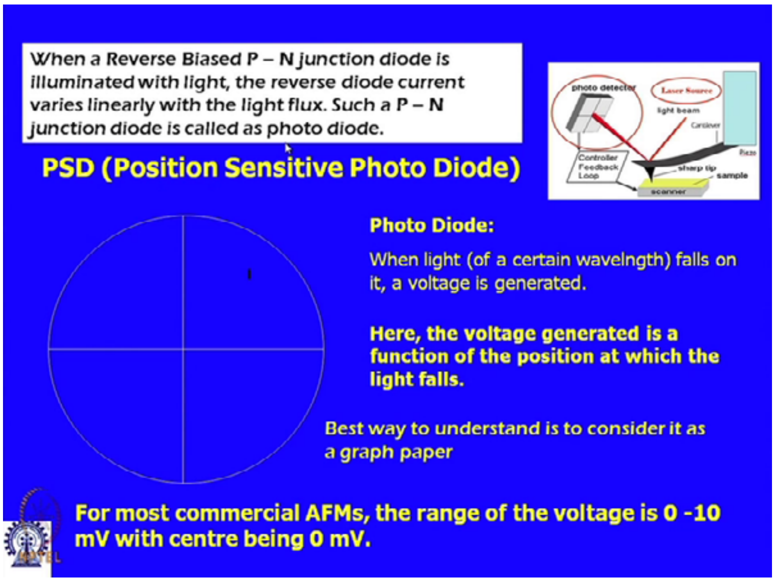

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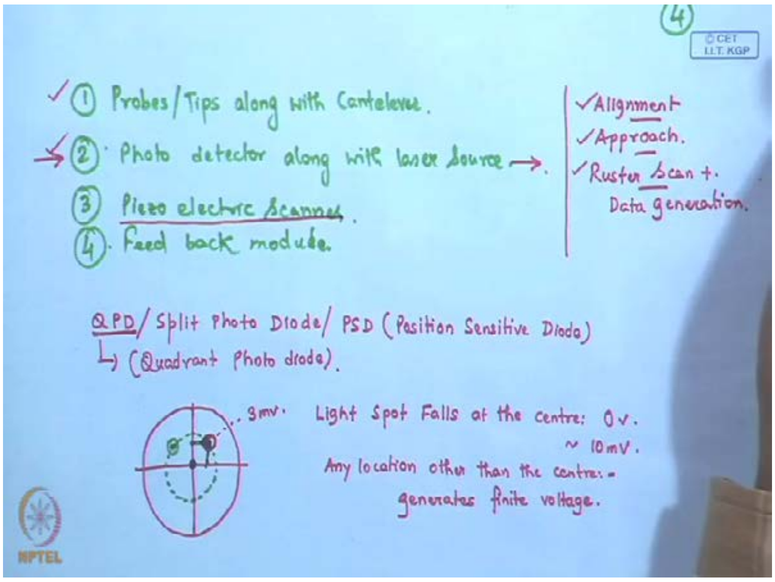

Next so, the if we look at the hardware elements we have talk about. Firstly, we had talk about the probes or the tips, the second 1 is the photo detector laser source, the third 1 is the piezoelectric scanner and the fourth 1 is feedback module. Feedback module is more of a controller, it is more of the classical feedback mechanism. So, there is nothing much to discuss, but this photo detector along with the laser source this is important and it requires for your attention to understand and once we are through with this hardware elements we will then focus our attention on to some of the operational aspect. We start of with alignment and then approach and then ruster scan and data generation. So, after this class and probably the subsequent class you will be able to understand these individual elements and these individual operations as well as how exactly and a f m generates an image. So, let us say what is a photo diode.

So, what we will be using is essentially a quadrant photo diode q p d, it is also often referred to as the split photo diode or the p s d position sensitive diode. And well, what exactly is a photo diode? So, when a reverse biased p n junction diode is illuminated with light, the reverse diode current varies linearly with the light flux such as a such a p n junction diode is called as a photo diode or in other words in very simple terms if you put if you a focus light on a photo diode a voltage gets generated and a position sensitive diode and quadrant photo diode what happens is the magnitude of the voltage is a function of the location where the light of the laser spot is shinning. So, the easiest way to understand from the standpoint of an a f m is to understand it from the point of graph paper.

So, let us say. So, this is photo diode. This might look gigantic , but reality is for a f m these is very small, the diameter is let us say few millimeter 5 or 6 millimeter and this is the center. So, if a laser will light spot falls at the center, it will generate zero volt. Typically in most commercial a f m if the light spots falls exactly at the periphery it sort of corresponds to a voltage of roughly 10 mill volt.

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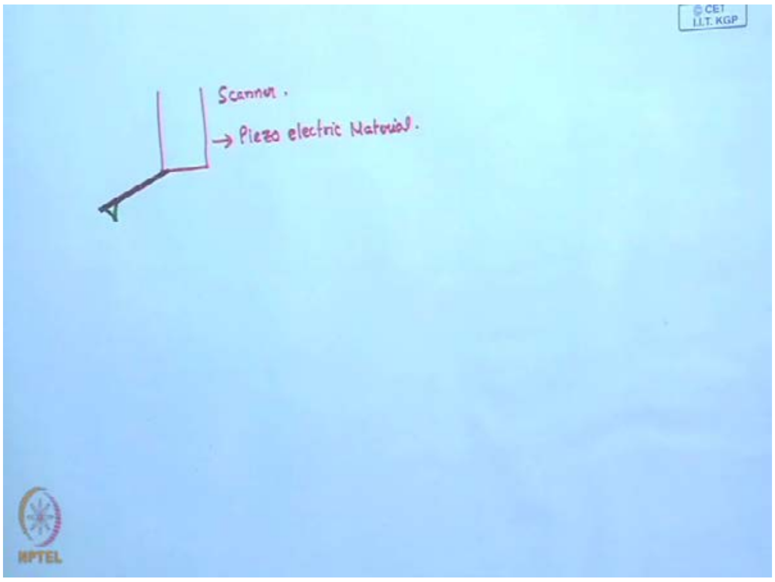

It can vary, really does not matter. Now, if this spot which can be a laser spot or a light spot falls at any other location, it generates finite voltage. It generates finite voltage. What we can find out from this q p d with the help of proper computer interfacing is the precise location. So, since we call it q p d and quadrant photo diode. So, 1 can split this location into let us say the x component and y component.

So, here for example, you can let us say that this totally magnitude corresponds to let us say 3 mille volt, but we can also find out what are the locations individual locations or individuals components of x and y over here from the q p d really does in mater you do not have to understand it in greater detail, but what you need to understand is how this light source comes and how this is useful in generating the scan. So, in other words what you can understand that the centre corresponds to 0 milli volt. So, let us say a circle, imaginary circle passing through this point around the concentric with the centre at all location the current will the voltage will corresponds through mill volt, but you can individually find out what is the x and y component and which will be different from this point and let us say this point. So, if somebody is interested you are encouraged to find out more detail, but this much is good enough for our understanding. So, the first what now we will do we will come back to the piezoelectric scanner after a while.

So, with the knowledge that it is say scanner mounted scanner is mounted to piezoelectric material and we have already talk that piezoelectric material is material to which if you apply a voltage it changes in dimension. Now, depending on whether the voltage buyers you are applying the positive and negative the change in and dimension will also accordingly vary. So, suppose if you have a piezo to which if you give a positive voltage, it might actually elongate. So, it might become short and it might become thin and tall. In contrast if you give now negative buyers negative voltage to the same piezo it will shorten so, it will become short and thin. So, this is the only thing probably you need understand, but maybe we will have some better idea about this piezo. With this much amount of understanding about the hardware.

So, we now understand the existence of the probe tips along with the cantilever, we understand the exiting the photo diode, quadrant photo diode, the position sensitive diode and may be in very simple terms what we also need to understand that we have a scanner which is let us say a piezo and in simplest terms let us understand that the cantilever is mounted to the bottom of this scanner.

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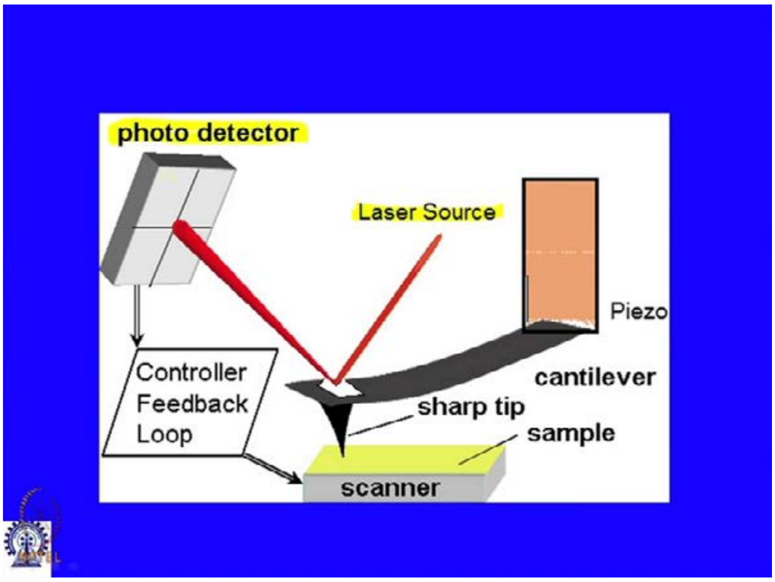

So, now if you apply a voltage to this piezoelectric scanner and it changes dimension according the cantilever surface will also come up come down or go up depending on the location of this piezoelectric scanner or the dimension of the piezoelectric scanner. We will revisit again. So, maybe it is a good idea to have a look at this particular we will see all this, photograph this gives you some data of idea now and I guess it makes some sense to you right now about the a f m. So, here is the laser source. We have talked about the photo detector, here we have drawn a square or a rectangular photo detector which is perfectly fine, but it can be secular detector as well. Key principle remains the same if the laser light is following on the at the centre it is 0 volt and further away you go from the centre there is a finite voltage gets generated.

We have a feedback loop which is shown schematically, you have the scanner over here to which is it is mounted to the piezoelectric material. You can identify now the sharp tip or the probe, you can identify the cantilever and you can identify this zone also what we talked as the as the shinning reflective zone on the cantilever which is right opposite to the location of the tip. Now, we will come to the concept of what is known as alignment.

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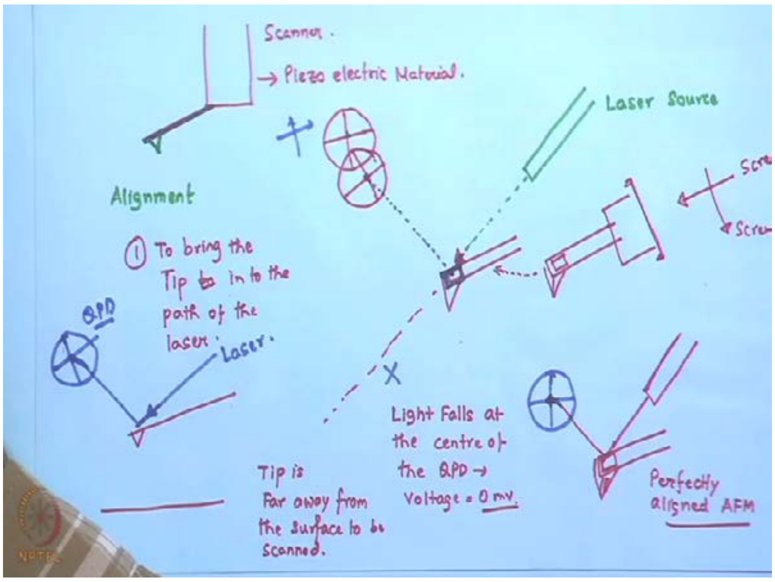

So, essentially idea is you have a laser source from which the laser light coming out, you mount your cantilever somewhere. So, you have a cantilever.

This is the reflective surface, this is the cantilever chip which is mounted to the cantilever holder which is attached to the instrument. The first step of your alignment and you have you also have you q p d, but initially you need to understand that the laser light goes a completely different direction and does not come and fall on the q p d. So, there is no reading on the q p d.

Your objective for alignment first is to bring the cantilever, the tip in to the path of the laser, how would that help? So, you have essentially have can have 2 different screws for giving a motion x and y direction. So, what you have to do you have to turn them in such a fashion so that the tip now moves in the desired direction and it comes now in to the path of the laser light. So, the moment this is the way the laser light was going, the moment the cantilever now comes in the path of the laser source if you remember correctly it has a shining area. So, the laser now falls on this shinning area which now acts as a mirror and gets reflected. So, the moment it gets reflected it is not travelling in this direction, it is now it is no longer travelling in this direction.

It is no longer going in this direction, but the laser gets reflected here. So, this is the first stage of alignment of the step of alignment and the second step of alignment it again you have 2 steps of screws which is attached to the to the mounting which holds the piezoelectric which holds the p s d photo diode. So, you term this photo diode etcetera whatever you want to do you move the diode a little with. So, that what happens is that the diode now is positioned in such a way that the laser light falls exactly at the centre. So, this is the final configuration after alignment. So, you have the laser light coming in, you have the tip on the path of the laser light, the light comes and falls on reflective area and it gets reflected in such a fashion that it falls exactly at the center of the q p d or the quadrant photo diode.

So, as you have already told that if the laser spot of the light falls at the centre of the q p d then voltage equal to 0. So, this is now what you can say is a perfectly aligned a f m, but still what you need to and understand is that even in this aligned a f m actually the tip is still far away from the surface to be scanned.

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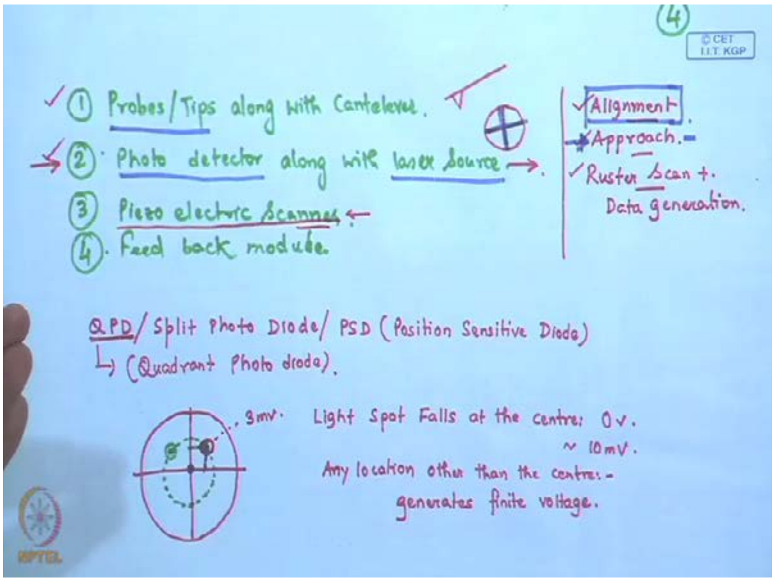

But you can have a configuration like this where this is your laser source and your cantilever is now in its path, it reflects away and it goes and it goes straight to the centre of the q p d. So, this is the perfectly aligned cantilever and now if you look at this particular image I guess you now can identify that well this actually shows that it is a perfectly aligned cantilever, forget about the scanner and sample part of it, but you see the laser the cantilever is in its path where it is get reflected and is falling on the centre of the photo detectors. So, this the perfectly aligned cantilever now. So, the way we are approaching. So, we now feel that we understand what the a f m probes are tips and cantilever are. We also understand the functionality about the photo detector along with the laser source.

So, we understand what exactly the laser is doing, we understand very briefly, but functionally what the what and photo diode suppose to do and we have also discussed the process of alignment. The next class we start discussing from the process of approach and then how the ruster scanning is done to generate an atomic force microscope image or data. Thank You.