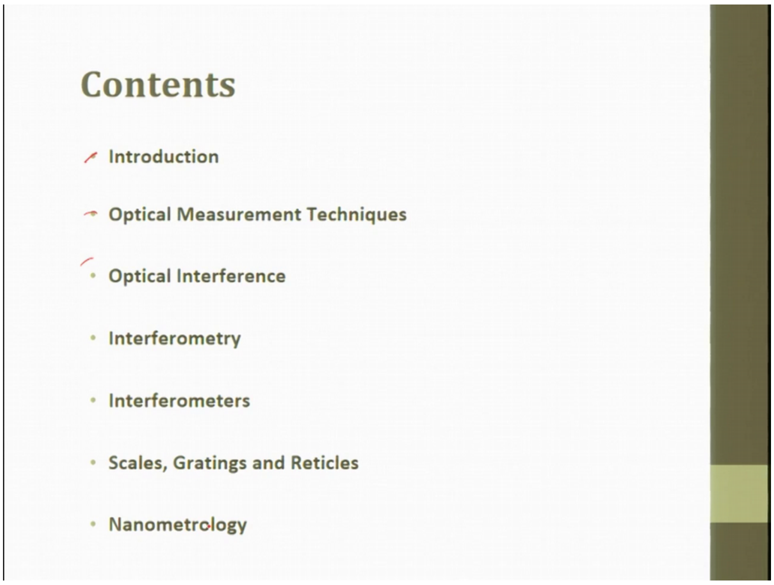
Engineering Metrology
Prof. J. Ramkumar
Dr. Amandeep Singh Oberoi
Department of Mechanical Engineering & Design Programme
Department of Industrial & Production Engineering
Indian Institute of Technology, Kanpur
National Institute of Technology, Jalandhar

Lecture – 32
Optical Measurements and Nanometrology (Part 1 of 3)

(Refer Slide Time: 00:19)

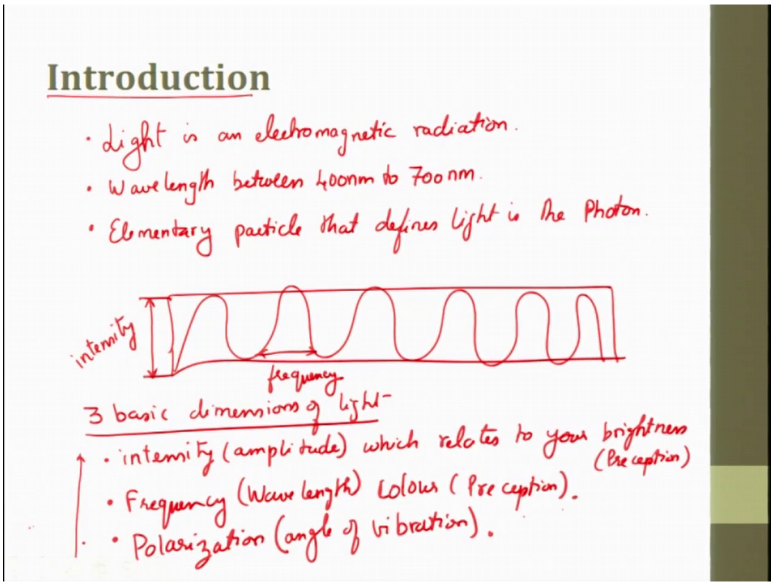
Welcome to the next chapter of discussion which is Optical Measurements and Nanometrology. Today we are more focused towards nano, because nano is 10 to the power minus 9 metre. We are trying to have more understanding of material process behaviour, when we look at this very small scales. So, we will try to cover how does the measurement happen at such small scales and also how is optical measurements, going to help us in this measurements field.

(Refer Slide Time: 00:54)



So, the content of discussion is going to be introduction followed by it we will have optical measurement techniques, optical interference, then different types of interferometry and then we will have scales gratings and reticles, then finally we will have Nanometrology to discuss.

(Refer Slide Time: 01:14)

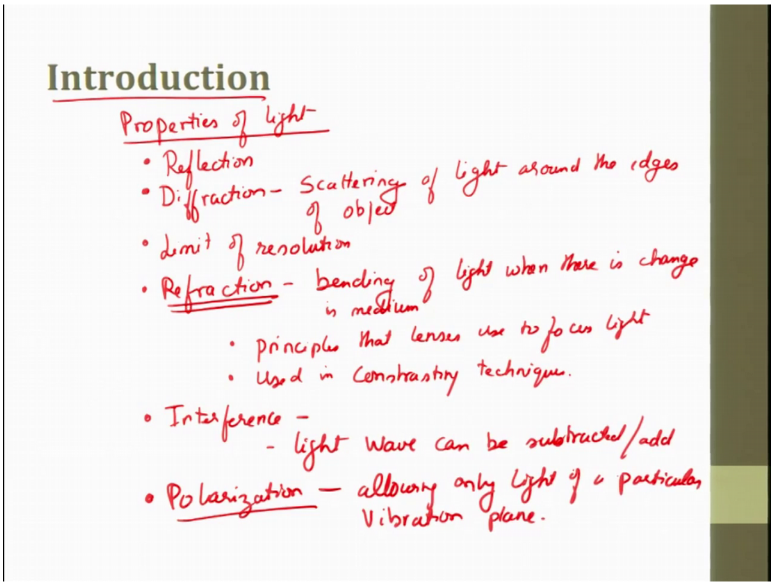


Let us first try to understand light. Light is an electromagnetic radiation ok. It falls in the wavelength between 400 nanometre to 700 nanometre. So, the element in elementary particle, particle that defines light is the photon and when we try to understand a wave.

So, this is called the intensity and this is called the frequency ok. So, what is intensity? So, in light there are 3 basic dimensions of light. So, light has only 3 basic dimensions, one is you try to play with the intensity of light. So, intensity is otherwise called as amplitude, which relates to your brightness; I would say perception right, perception of brightness.

Then frequency: frequency is otherwise represents as wavelength which relates to colour and I repeat it is again a perception ok. The last one is polarization, which is a very very important parameter. There are lot of instruments which work on this polarization which is nothing but the angle of vibration. These are the 3 dimensional parameters so of for light. So, if you can play with it, tweak with it, tailor it. So, then you get whatever requirements you want, polarisation is angle of vibration.

(Refer Slide Time: 04:46)

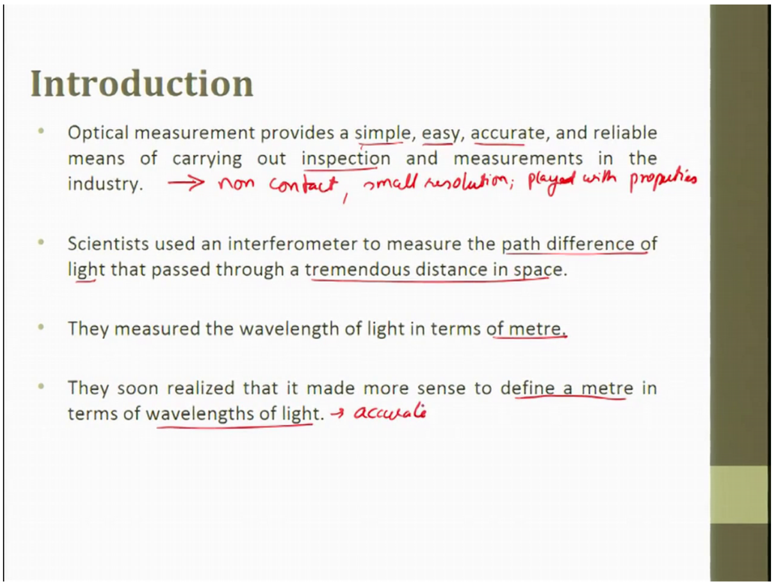


So, these are the 3 basic dimensions of light. When we talk about the properties of light, we have reflection, we have diffraction which is nothing but scattering of light around the edges of object, that is diffraction. Then limit of resolution then it is refraction which is nothing but bending of light when there is a change in medium ok. So, here we always talk the principles that lenses used to focus light for example, you can use lamp then you use oil. So, which change the then used in contrasting techniques. So, we also use refraction principles; diffraction and refraction are different.

Then, we will look at interference which is exhaustively used lot of applications. Today if you want to measure the linear displacement, we use interferometry techniques to measure. So, here the light wave can be subtracted or added. So, that you get whatever you want and the last one is polarisation, which I said last time also it is the vibration. So, allowing only light of a particular vibration plane, this is very important. Lot of applications are reflect the polarization is used in optical lenses with they are also used in spectacles.

So, these two whatever we have discussed till now is the basics of light. Light is an electromagnetic radiation, so you can play with it. It falls in the wavelength of 200 nanometre to 700 nanometre. The elementary particle that, defines light is photon. So, lasers and work on the principle of this photon energy packets. So, the wave the lights can be basically can have basic dimensions are 3 things. One is intensity, frequency and polarization; and the 3 principles is the reflection, diffraction, refraction and interference are some of the properties, which are used in properties of light, which are used for developing instruments for measurements.

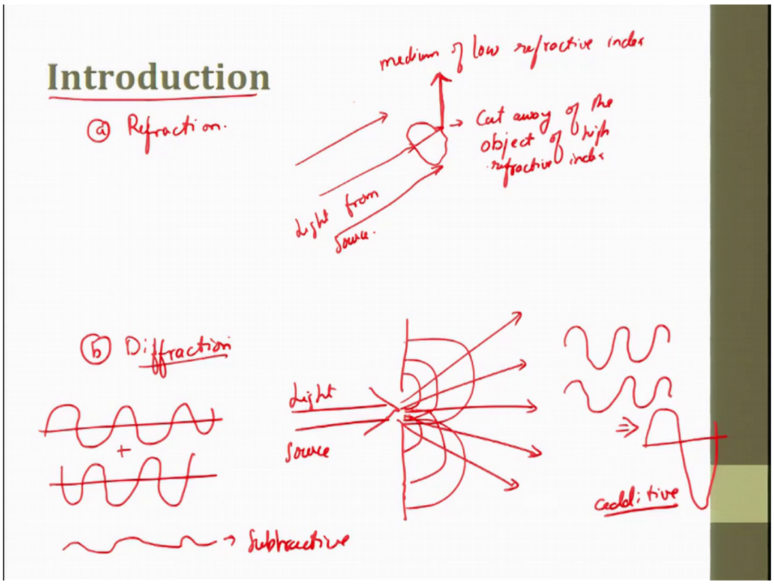
(Refer Slide Time: 08:33)



So, optical measurement provides a simple easy accurate and reliable means of carrying out inspection and measurement in the industry. It is predominantly non contact. So, once it is non contact then, it gives you a flexibility of measuring very small resolutions. So, it can also be played very easily for example, you have understood the properties you can play with the properties, properties to get whatever information you want, when it is very reliable ok. Scientist used an interferometer to measure the path difference of light that passes through a tremendous distance in space; we use interferometers. They measure the wavelength of light in terms of metres, they soon realise that it is made more sense to define a metre in terms of wavelength of light.

So, first they defined the wavelength in terms of metres, then they started defining the metre in terms of wavelength, because it was very accurate.

(Refer Slide Time: 09:48)

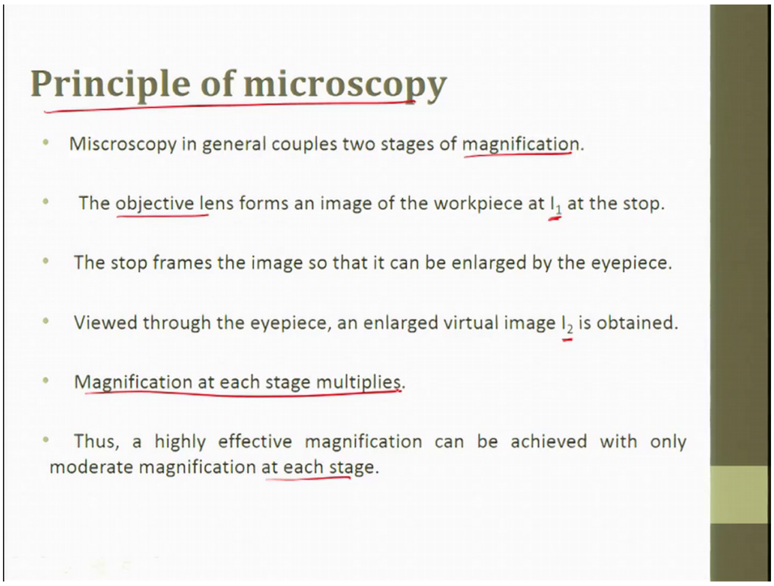


In introduction, we also have 2 things, which I already discussed. One is refraction; the other one is going to be diffraction. So, here if for example, you have a droplet of water this is how the light is passing. So, then what will happen is it will try to pass through and bend. So, this is light from source we will put, this is a medium of low refraction index refractive index. So, you can see the light bends. So, this is called as the, it is cut away of the object and then it bends.

So, it cuts and then it bends ok. So, when I talk about diffraction, you will have a source of light coming then you have a slit. So, you can see light going by. So, the light will pass through several of these sources and you can see this is a light source. So, here what happens is you can have 2 types of images. One is constructive image for example you have one light coming like this, the other light is also of the same thing. So, then this is equal to a construct to you can have an added or constructive fringe patterns.

And when you want to do subtractive, you can suppose you have 2 wavelength of light coming like this and here it is on the other way around. So, then what happens, when these two are added? So, you will always get something like a very low subtractive. So, this is subtractive interference pattern, which is coded this is additive interference pattern it is given. So, you see the wavelength is added the amplitude is added, the amplitude is subtracted with these techniques; you can try to play with light.

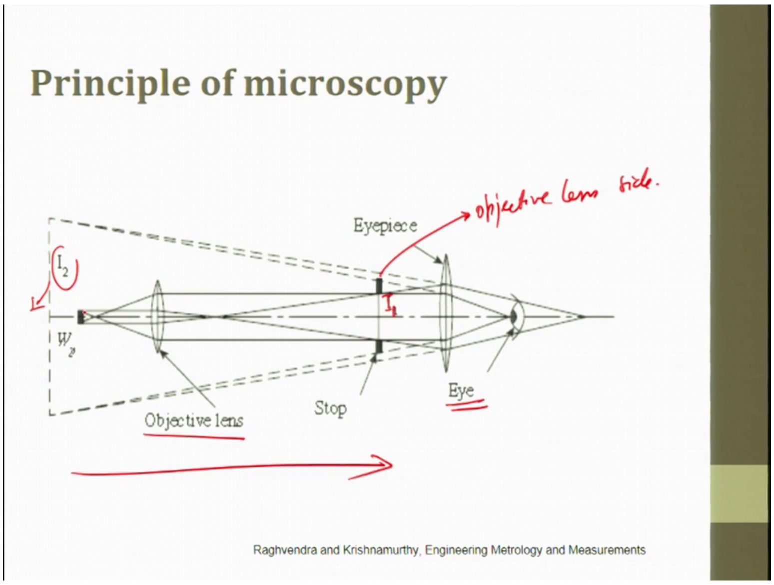
(Refer Slide Time: 13:03)



So, let us look at a principle device, which is a microscope, which is exhaustively used which works on the principle of optics. Microscope in general couples 2 stage of magnification. The objective lens and then it is there, we have one magnification the other one we will have at close to the eyepiece ok, the objective lens forms an image of work piece at l 1 at the stop. The stop frames the image. So, that it can enlarge by the eyepiece, view through the eyepiece and enlarged virtual image I 2 is obtained.

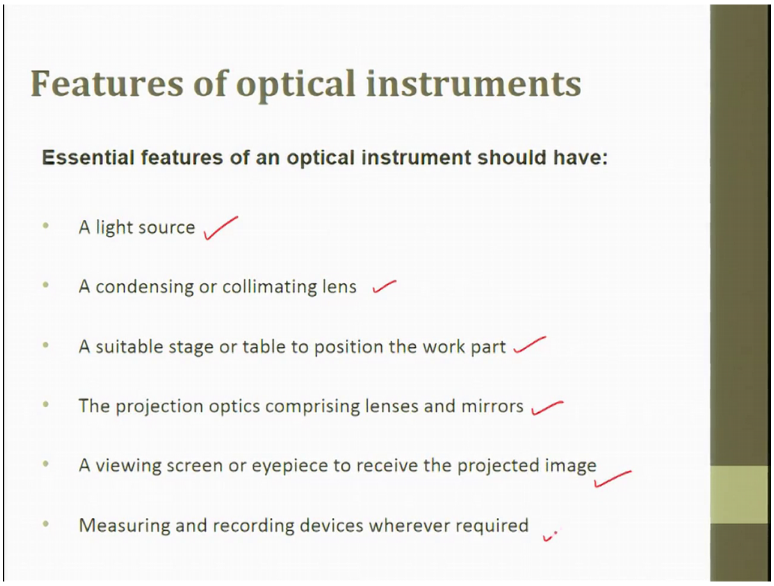
So, magnifications at each stage multiplies; thus, highly effective magnification can be achieved with only moderate magnification at each stage.

(Refer Slide Time: 14:05)



So, the most important thing is magnification at each stage gets multiplied. When you look at it, this is what is I 1, which I told you the objective lens forms an image this is objective lens. So, this is objective lens side, objective lens side ok. So, here you have. So, the image objective lens forms an image of the work piece at I 1 at a stop, then the stop frames the image. So, that it can be enlarged by the eyepiece view through the eyepiece and enlargement happens at I 2. This is I 2 ok, this is I 2. So then finally, this is the objective lens this is the objective lens and this is your eyepiece.

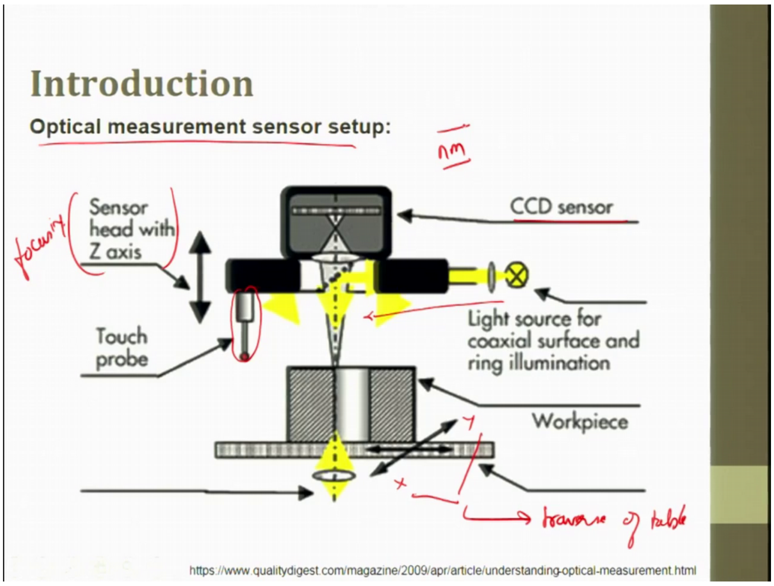
(Refer Slide Time: 15:13)



So, you try to view like this is the stop whatever we have talked about this is the eyepiece this is the objective lens, and here is a plane, and here is the work. So, magnification can happen at several stages thus highly magnification can be achieved only by moderate lenses.

Essential features of an optical instrument should have a light source, a condensing lens, a suitable stage or a table to position the work; work part then projection optics comprising lenses and mirrors then screen for viewing and then measuring and recording devices.

(Refer Slide Time: 15:36)

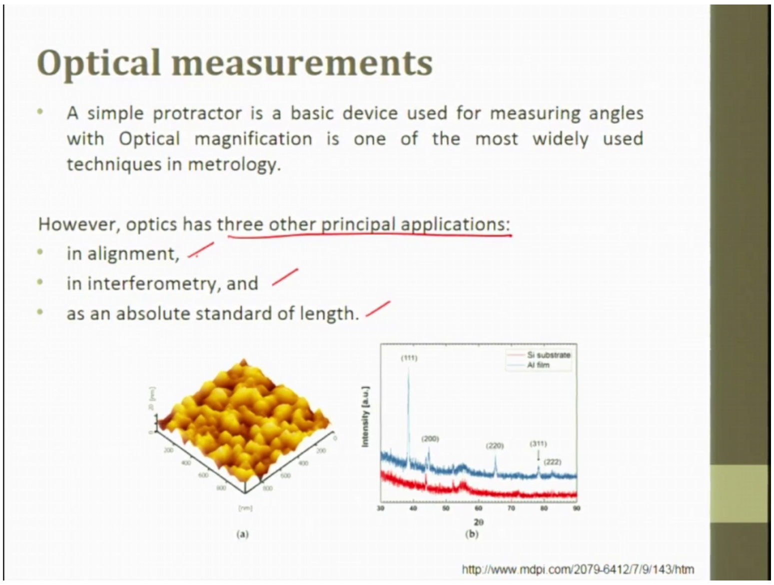


These are some of the Essential parts of an optical microscope. You can see here an optical microscope. So, an optical microscope we have this is a light source. So, light source headset then, there is a beam splitter; so then it moves towards it moves towards the work piece. So, here is a work piece. And then the work piece is resting on a table, which can go in X X and Y direction you can move it and then the light gets reflected back. So, then there is a reconstruction happening, a fringe is happening and that is recorded at CC charge coupled device sensor it is getting done.

So, in this optical microscope it is also interesting to note that, they also have a touch probe. So, it is used to give a high, it is used to give a rough estimate or rough or low resolution measurements can be done here. And then we get into optics, where in which a high resolution can be done here. So, light source for coaxial surface and ring illumination. So, there is a light source which comes and then this is the touch probe, which can go the sensor heads with the Z direction for focusing you can move. So, this portion takes care of the focusing and this X Y tries to take care X and Y, they try to take care of the traverse of table.

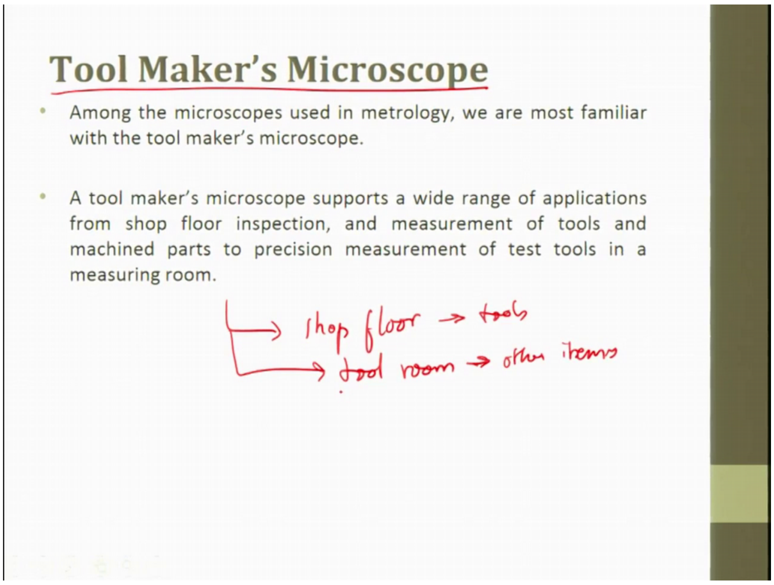
So; that means to say you can measure the entire work piece. So, this is an optical measurement sensor setup, which is used today for measuring the height in nanometre level.

(Refer Slide Time: 17:23)



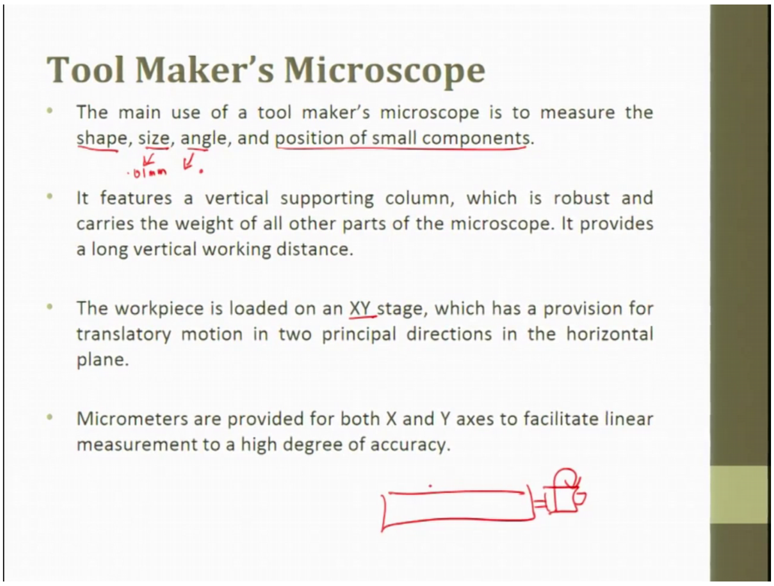
Heights can be measured. A simple projector is a basic device used for measuring angles with optical magnification is one of the most widely used technique in metrology; however, optics has 3 major applications in alignment application, we use optics in interferometry, we use optics for measuring the distance. And it is also used as absolute standard for length that is what we measure the length, 1 metre is measured in the wavelengths today. So, these are the 3 other basic application of optics in measurement.

(Refer Slide Time: 17:55)



The most commonly used one microscope in the shop floor is tool maker's microscope, amongst the microscope used in metrology, we are most familiar with the tool maker's microscope. A tool maker's microscope supports a wide range of application from shop floor inspection and measurement of tools and machine parts to precision measurement of test tools in the measuring room. So, it is used in shop floor for measuring the small deviations and it is also used in tool room ok. So, here it is more predominantly of tools here the other items, we use this tool maker's microscope.

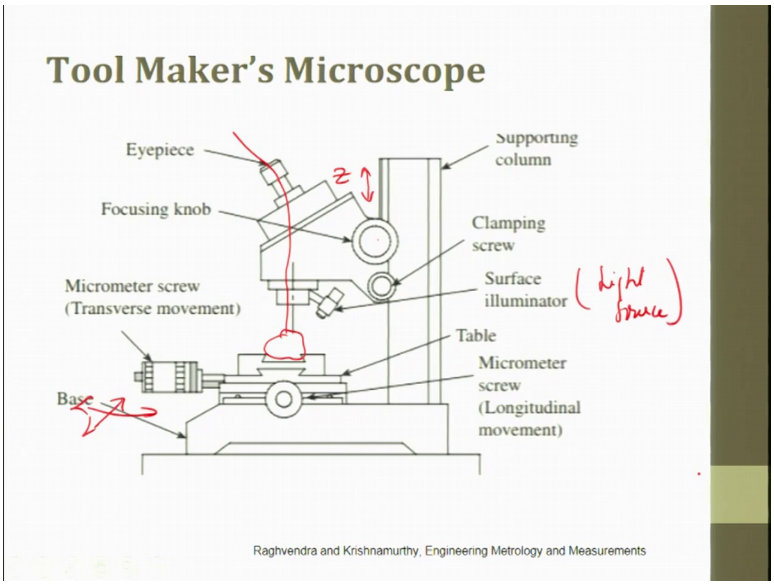
(Refer Slide Time: 18:45)



The main use of tool maker's microscope is to measure the shape, size, angle and the position of small components here, we talk angle accuracy in terms of degrees the shape depends on the stage what you traverse size what we talk about is we talk close to 0.01 millimetre. The position of the small components also can be measured by using the tool maker's microscope. It features a vertical support column, which is robust and carries the weight of all other parts of the microscope, it provides a long vertical working distance.

So, Z so; that means, to say you can keep a large workpieces there, the workpieces loaded on XY stage, which has a provision for translatory motion in 2 principal directions in the horizontal plane that is X and Y and then it the micrometres are provided for both X and Y. So, that as and when you move you see the micro so, what they are trying to say is you have a table. So, here you will have a micrometre. So, whatever this rotates, you can measure it at a very small accuracy.

(Refer Slide Time: 19:58)

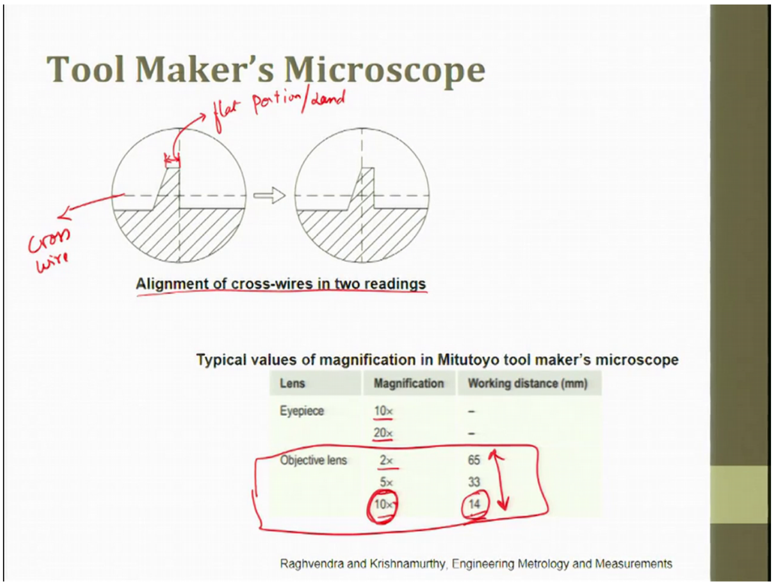


So, this is a typical tool maker's microscope. So, this is the column which tries to take the load.

So, here is the clamp. So, you this gives you a freedom of this motion up and down. So, you also have a focusing knob. So, this focusing knob and the clamping screw helps you to for height measurement adjustments and then you have a table these are the micrometre scales which are there. So, this is for Z measurement and here you have a X and a Y table for movement.

So, this is in micrometre, this is for longitudinal, this is for transverse direction and here is the illumination this is nothing, but the light source, there is a light source this tries to fall on the object which is kept here and then you try to measure it. You try to measure it and then try to see; what is the change in shape, size, angle and even the dimensions of very small components.

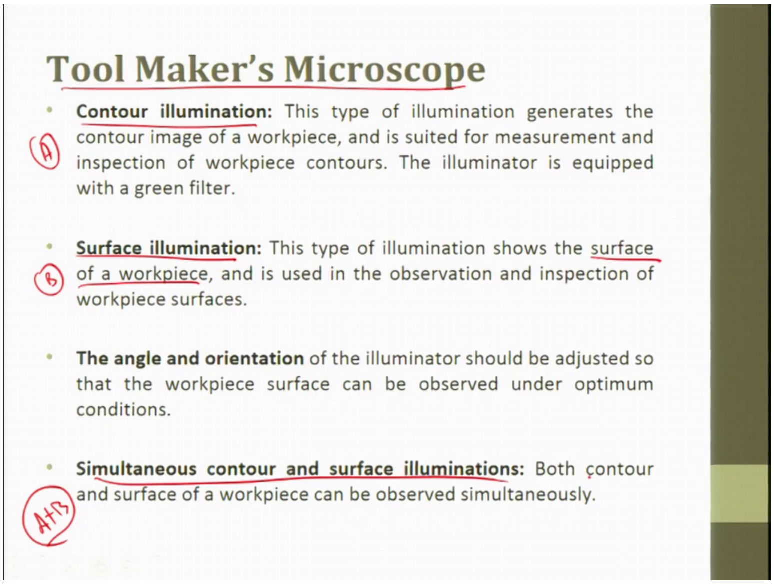
(Refer Slide Time: 20:56)



So, in a tool maker's microscope you will always for alignment purpose, this is very important alignment of cross wire in reading. So, you have to measure the flat portion the flat portion or the land ok, which is called as a land. If you want to measure so, first what do you do? Is you put the focal you add the eyepiece, you will always have this is as the cross wire. So, this cross wire is aligned to one side of the of the one edge, where the land starts and you have to move it to the other end of the land starts and then you try to get the readings ok.

So, here you should also understand there are magnifications also there. So, you can have at the eyepiece 10 x, 20 x and then objective you can have 2 x, 5 x and 10 x, you can see the working distance as and when the objective X increases the working distance go small. So, this is a very very important parameter you should know, when you try to look at very high magnifications, you should understand you are sacrificing the working distance.

(Refer Slide Time: 22:14)

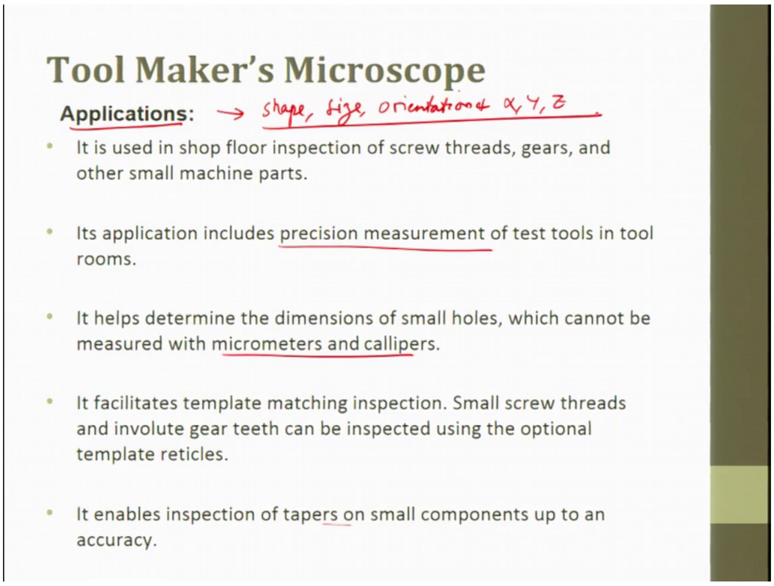


So, these are the different types of illumination, you can have and more details about the tool maker's microscope. Contour illumination can be done, this type of illumination generates the contour image of the work piece and is suited for measurement and inspection of work piece contour, the illuminator is equipped with a green filter. So, now that you can also try to place you know I have said 3 basic parameters, one is wavelength amplitude and then you have the polarization.

If you can play with these parameters, then you can try to get more clarity in the image. Whatever you are used for measurement suppose if there is a image work piece which is too complex in nature. So, what we do is we try to make a contour of it, put in the eyepiece or have a projector and then have it as a mask there and then project the screen project the work piece dimensions. So, you can you easily do comparison and try to also measure the deviations.

The surface illumination this type of illumination shows that the surface of the work piece and is used in the observation and inspection of the work piece. So, shows the surface of the work piece surface illumination the tool maker's microscope, what we showed you here is surface illumination. So, instead of the surface illumination you can have contour illumination, which was the first thing which we discussed, the angle and the orientation can also be done of the illuminator should be adjusted. So, that the work piece surface can be observed under optimum conditions and then simultaneous contour and surface illumination is also possible suppose this is A this is B.

(Refer Slide Time: 24:07)



So, this is nothing, but A plus B both contour and the illumination can be done simultaneously to measure the tool work piece deviations.

What are the applications? It is used in shop floor inspection of screw thread gear and other small machine parts. It is application includes precision measurement of test tools in told room, it helps to determine the dimensions of small holes, where calliper cannot micrometre cannot be used it facilitates template matching inspection. So, it is something like a comparator it enables inspection of taper of small components also. So, basically what it says shape, size, orientation, and X Y Z coordinates can all be measured using this tool maker's microscope.

Thank you.