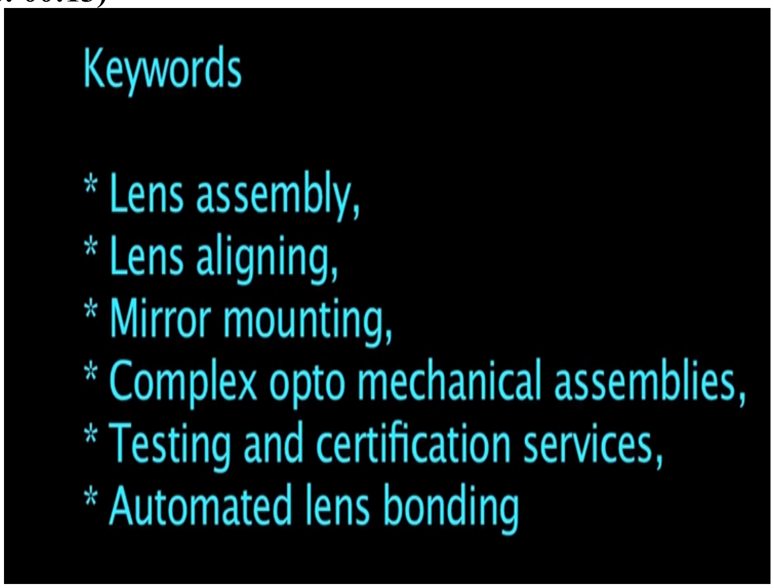
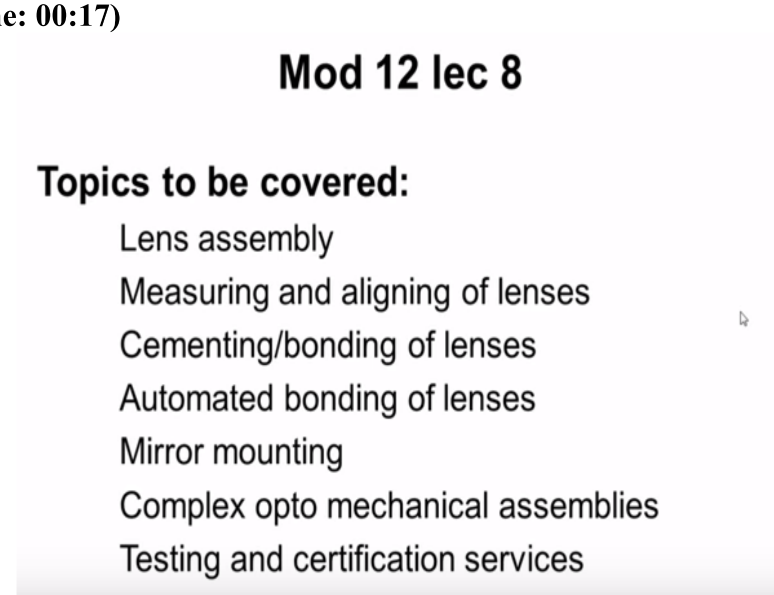
Metrology
Prof. Dr Kanakuppi Sadashivappa
Bapuji Institute of Engineering and Technology Davangere

Lecture – 44
Complex Opto- Mechanical Assemblies, Metrology Testing and Certification Services

(Refer Slide Time: 00:13)



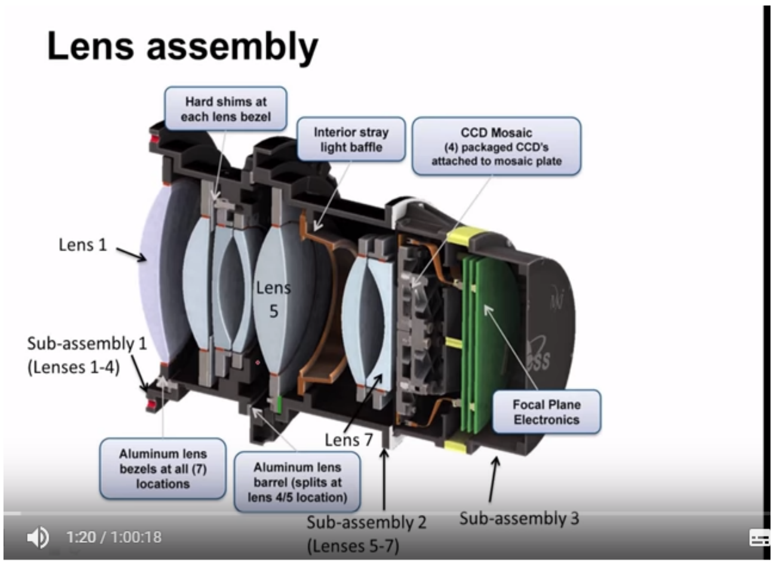
(Refer Slide Time: 00:17)



Welcome back to the metrology lecture series, now we will start module 12, lecture number 8. In this lecture, we will be covering the following topics. We will continue the discussion on the optical system design in which we will be studying lens assembly, measuring and aligning of lenses, cementing and bonding of lenses in which we will cover the manual cementing of lenses, as well as automated bonding of lenses.

And then how to mount the mirrors with the optical systems and then we will discuss about some complex opto mechanical assemblies and finally, we will be discussing about testing and certification services connected with the metrology.

(Refer Slide Time: 01:20)

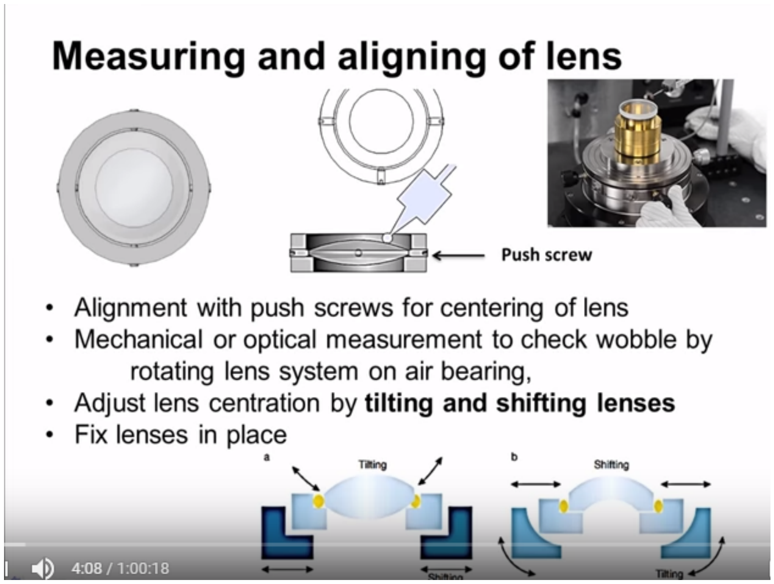


Now we will start the discussion on lens, possibly we can see here optical assembly, so this assembly consists of totally 7 lenses, lens, 1, 2, 3, 4, 5, 6, and 7 lenses. Seventh lens is plano concave lens and lens number 3 is also plano concave lens. Now lenses 1 to 4, they form sub assembly number 1, so we can observe here, this is the barrel, it is a split barrel, we can see here, so this portion is sub assembly number 1, it consists of 4 lenses and we can see the retainer rings.

Here also we have retainer ring to retain the lens and then between 2 internal rings, we have shim plates for adjusting the axial alignment of lenses. Now sub assembly number 2 consists of again 3 lenses, lens 5, 6 and 7, so these 3 lenses are assembled in another split barrel, so this is the second barrel in which these 3 lenses are mounted and now we can observe in sub assembly number 2, we have interior stray light baffle, which will reduce the stray light inside the barrel.

And since this stray light is reduced, the contrast of the image will increase. Now we can see the sub-assembly number 3, it consists of the electronic circuitries CDs attached to Mosaic plate that we can observe here and also we can observe focal plane electronic circuit bolts. Now all the 3 sub-assemblies are assembled using appropriate mechanical fasteners.

(Refer Slide Time: 04:08)

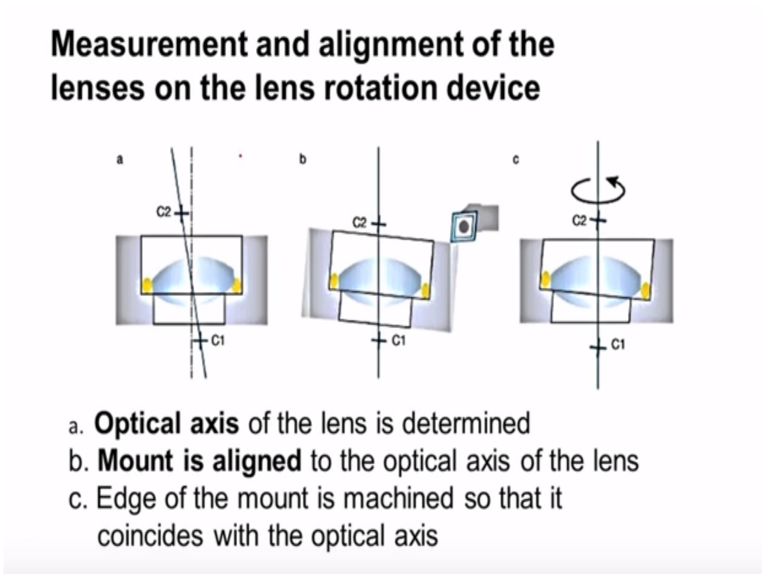


Now, we will see the measuring and aligning of lenses, now in the different lenses are assembled in the barrel, now we have to align them properly, so that the optical axis of all the lenses aligned with the barrel axis, so that we get quality image. We can see an assembly of lens here, which is properly aligned and mounted. We can see the barrel body here and we have placed the double convex lens in its seat.

Now we can measure the alignment by rotating the lens, we can measure whether there is any wobbling, so that for measuring the wobbling, we can either use the mechanical measurement system or optical measurement system. A dial indicator is a simple mechanical measuring unit, we can use sealer gauge also for measuring the alignment and wobble, so we should have a rotating lens system normally mounted on air bearing, so that the out of plane movement is reduced.

So we have to slowly rotate the rotating lens system and the measurement system, we will measure the wobble and if there is any wobble, we have to adjust lens centration either by tilting or shifting the lenses, we can see here. We can tilt the lens or we can shift the barrel, otherwise we can shift the lens and tilt the barrel for aligning the lenses with the barrel. Once they are aligned, we have to apply the polymer and we should fix the lenses in place.

(Refer Slide Time: 06:29)

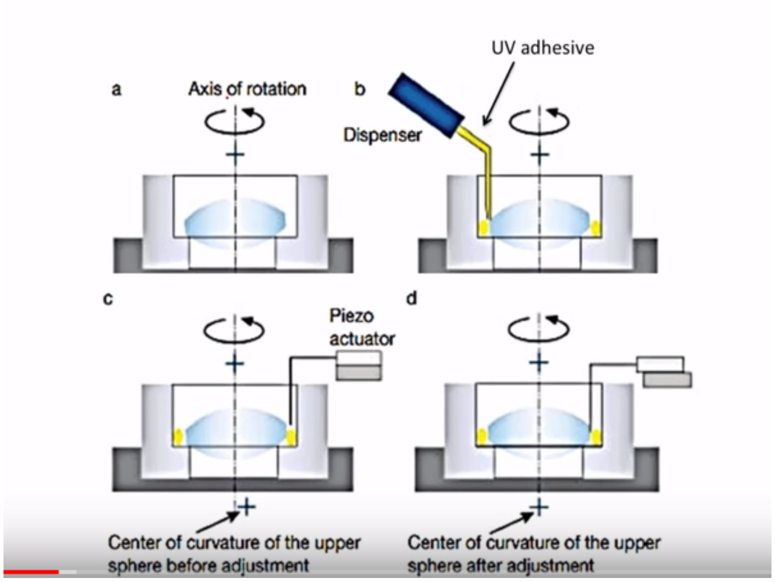


Now, we can see the measurement and alignment of the lenses on the lens rotation device, so this is the barrel mounted on the rotation device, which is mounted on air bearing, so we have to rotate this cell and you can see here, now in the first picture, the optical axis of the lens c1, c2, the line joining c1 c2 is a optical axis of the lens that we have to determine using the measurement device and then we have this is the mechanical axis of the barrel, now there is some misalignment.

So we have to adjust the mount or cell, mount is aligned to the optical axis of the lens, we have to tilt the mount, so that the axis of the mount coincides with the optical axis and then they have to machine the edge of the mount. Edge of the amount is machine, so that it coincides with the optical axis, now we can see in the 3rd picture, the optical axis of the lens is coinciding with the mount axis.

So this measurement and alignment either you can do manually or you can always use some automatic aligning machines, which uses software for measurement of centering error and for alignment purpose.

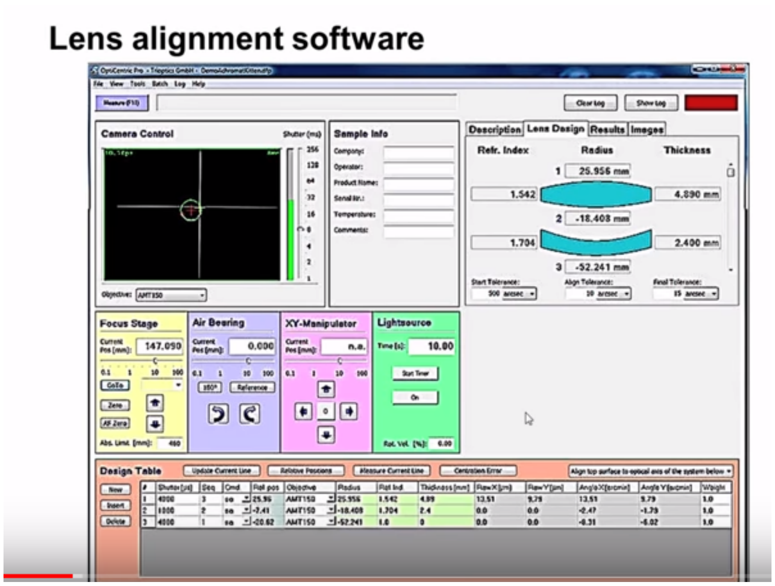
(Refer Slide Time: 08:16)



Now, you can see a set of pictures here, so in picture a, we have the axis of rotation, this is the cell and is the seat for lens and lens is placed at the seat and then after proper alignment that is either by shifting the lens or by tilting the lens, we have to see that optical axis is a lens coincides with the cell axis and then after adjustment, after centering, we have to apply the adhesive, UV adhesive can be used.

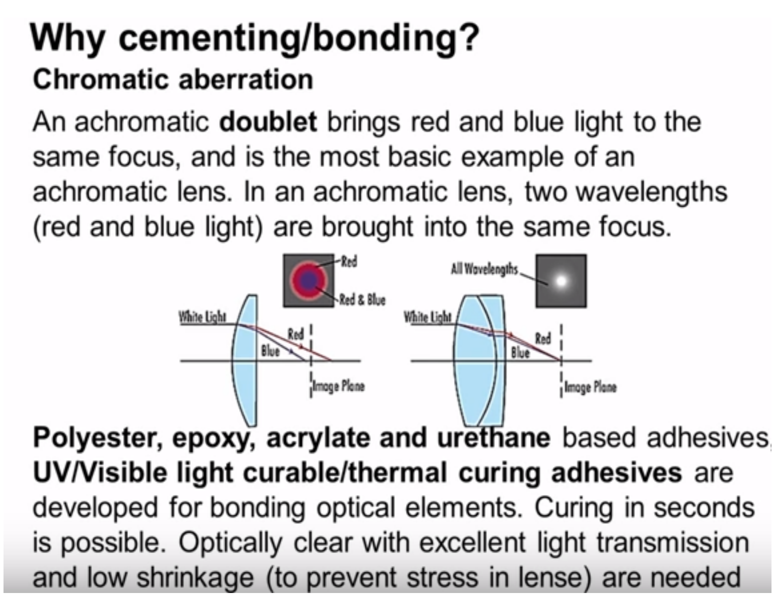
So that the lens is fixed in its the seat, now for adjustment, we can always use a piezo actuator for tilting and shifting of the lens, so in picture c, and picture d, we can see how the alignment is carried out using the piezo actuator. Once the lens is centered, we have to apply the adhesive, so that it is fixed at the cell body.

(Refer Slide Time: 09:25)



Now we can always use lens alignment software, so if we use automatic centering and bonding machines, it uses a software for measurement of centering error and for adjusting, for eliminating the error or for adjusting the lenses. We can see the video display, which shows the de-centering error, we can always measure the radius of lens, thickness of lens and then calculate software will calculate what is the amount of centering error and then alignment is carried out, so that centering error becomes 0.

(Refer Slide Time: 10:12)



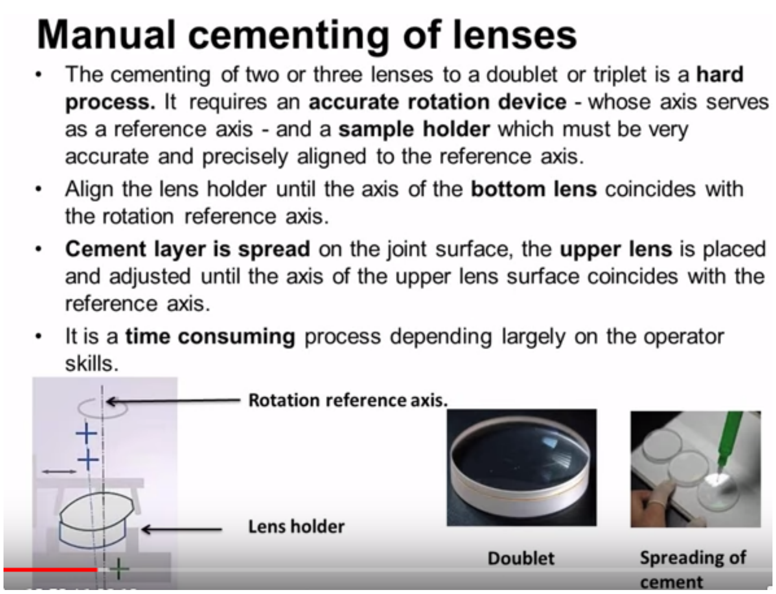
Now sometimes 2 or 3 lenses are bonded together to make doublet or triplet, now we should understand why this bonding of lenses is required, so now we know that chromatic aberration is a sort of error that happens in the optical system. If we use a single lens as shown here, this lens will split the white light into its component colors, we can see here red light is focused at a longer distance from the lens surface and blue light is refracted more and it is focused at a little distance from the lens.

So because of this the chromatic aberration occurs and the image will not be sharp, so to eliminate this chromatic aberration, 2 to 3 lenses are bonded together and now we can see in this picture, 2 lenses are cemented or bonded together. Now in this case, white light it enters the 1st lens and again the refracted in the 2nd lens and finally, the different components of white light, they are focused at the same focal point and then we get a very sharp image.

So to eliminate chromatic aberration, cementing of lenses is needed, so different adhesives are available in the market, polyester, epoxy, acrylate, urethane-based adhesives are available. Ultraviolet visible light curable and thermal curing adhesives are also developed for bonding the optical elements, so curing is possible in a few seconds.

So the cement should be optically clear with excellent light transmission capability and the shrinkage of the cement should be very less in order to prevent stresses in the lenses.

(Refer Slide Time: 12:57)



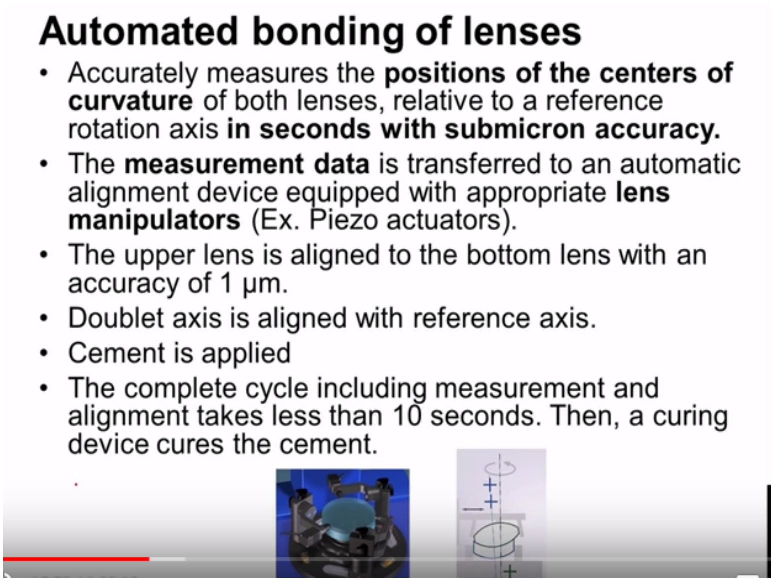
Now let us understand the manual cementing of lenses we can see in this picture, we have set of lenses, 2 lenses are there, which are to be cemented and they are placed in a lens holder and then we have a rotation arrangement, which rotates the lenses and this rotation arrangement is based on air bearing for precise rotation of the lenses. The cementing of 2 to 3 lenses to a doublet or triplet is very hard process, time-consuming and cumbersome process.

It requires an accurate rotation device, whose axis serves as reference axis, sample or lens holder is needed, which must be very accurate and precisely aligned to the reference axis. Now we should align the lens holder until the axis that means we have to place the 1st lens in the lens holder and we have to rotate the lens holder and we have to align the lens holder until the axis of the bottom lens coincides with the rotation reference axis, that means by tilting or shifting of this bottom lens.

We have to make sure that the axis of 1st lens coincides with axis of reference axis and then we have to place the 2nd lens, which is to be cemented. Before placing, we have to apply the cement on the surface of the 1st lens and it should be spread properly and then the upper lens is placed and again it should be tilted and shifted, so that the optical axis of the second lens coincides with optical axis of the 1st lens and we should see that the combined axis of the doublet coincides with reference axis.

So that way we have to manually adjust the lenses, shifting and tilting of lenses we should make and finally, we will get cement doublet or triplet, so this is a very time-consuming process and it largely depends on the operator skill.

(Refer Slide Time: 15:50)



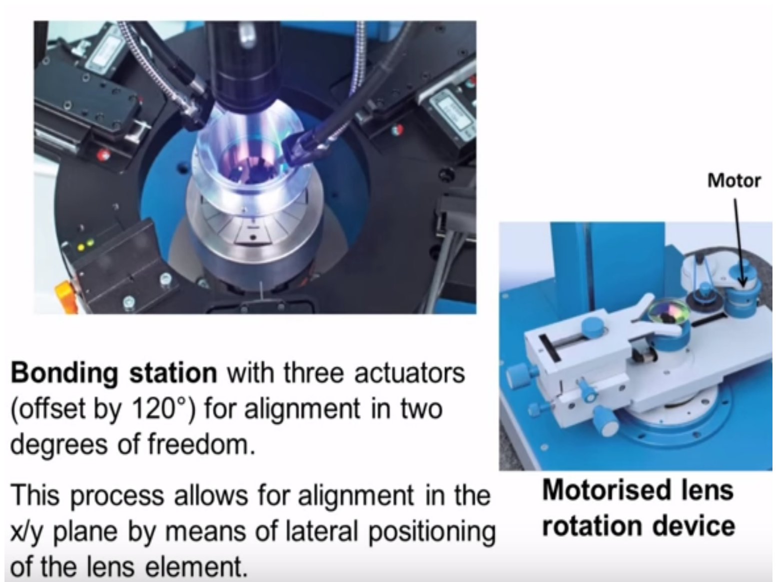
Now in order to make the cementing easy and effective, automated bonding systems are developed, these systems automatic bonding systems accurately measure the position of the center of curvature of the lenses to be cemented relative to a reference rotation axis, so this process takes1 or 2 seconds and the accurate measurement is possible with submicron accuracy. The measured data is transferred to an automatic alignment device, which is equipped with appropriate lens manipulators such as Piezo actuators.

So in the diagram, we can see the Piezo actuators. These actuators shift and tilt the lenses, so that the optical axis of lenses coincides with rotation axis. The upper lens is aligned to the bottom lens with an accuracy of 1 micron and then cement is applied and then 2nd lens is placed. The doublet axis that means axis for the 2 lenses is aligned with reference axis, again it takes 1 or 2 seconds.

Now let us discuss it would automated bonding of lenses. The automatic bonding systems accurately measure the positions of the centre of curvature of the lenses relative to reference rotation axes, so they can measure the positions in 1 or 2 seconds with submicron accuracy, so in this diagram, we can see the arrangement of automated bonding system. The measurement data is transferred to an automatic alignment device equipped with appropriate lens manipulators such as Piezo actuators.

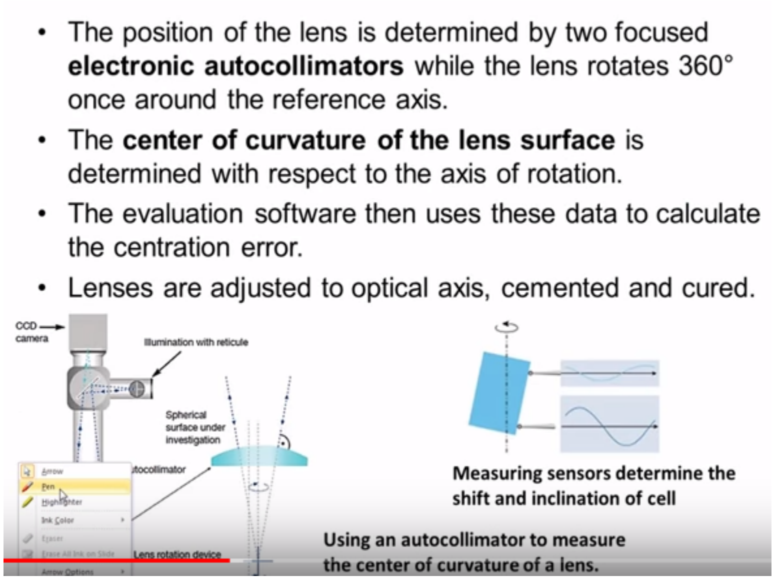
So we can see the arrangement here, so the 2 lenses are placed on a rotation device, which is mounted on air bearing, so the lenses are rotated and the optical axis of lenses are determined and by using these manipulators, the lenses are shifted and tilted, so that the optical axis of lenses coincide with the rotation reference axis. The alignment of lenses is carried out to an accuracy of 1 micron and cement is applied and cured. The complete cycle including measurement, alignment, bonding and curing takes place in less than 10 seconds.

(Refer Slide Time: 19:11)



Now, you can see a close view of a bonding station with 3 actuators, we can see here, we have 1 actuator here, the 2nd actuator here and the 3rd actuator here. We are using 3 actuators normally Piezo actuators, the lenses can be moved in XY plane and then they can also be tilted, so that the axis of lenses coincides with rotation axis, so in this view we can see an arrangement for rotating the lenses, this is the stage rotating the stage on which the lenses are placed and this is the motor to rotate the rotation device.

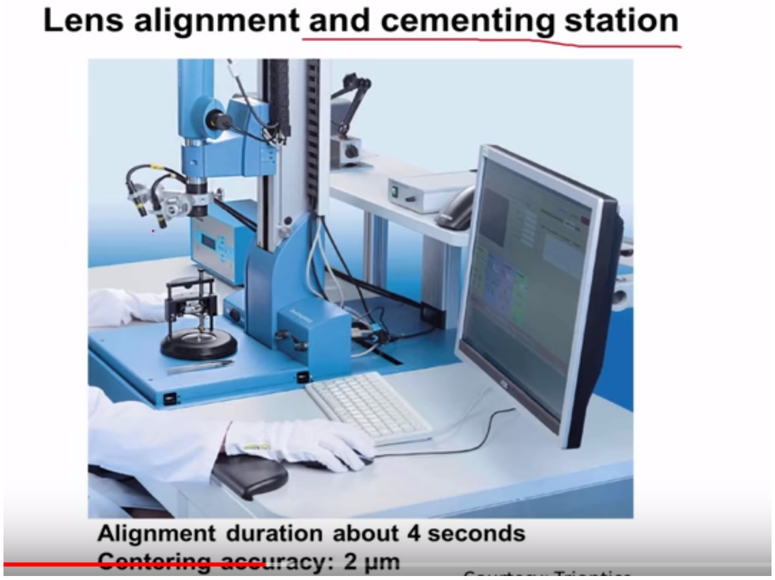
(Refer Slide Time: 20:04)



Now the position of lenses is determined by using the electronic autocollimators, so the lenses are rotated through 360 degree once around the reference axis and then centre of curvature of lens surfaces are determined with respect to the axis of rotation and these data are transferred to a software. The software will calculate what is the amount of centration error and signals are sent to the lens manipulators and lenses are adjusted to optical axis, cemented and cured.

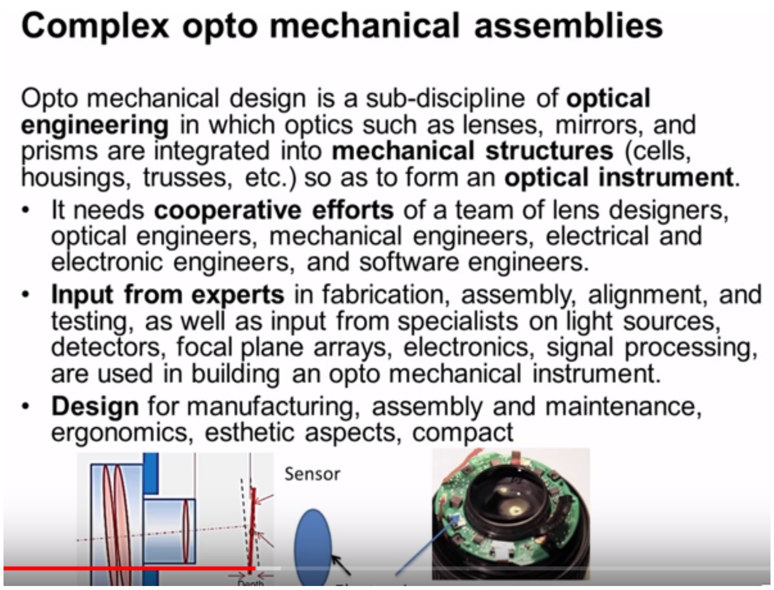
So you can see the arrangement of autocollimator and this is the lens rotation device and lens placed on the lens rotation device and this is the axis of rotation, also sensors are provided to determine the shift and inclination of cell, so if necessary the cell is also shifted and tilted for aligning the rotation axis or the cell axis with the lens axis.

(Refer Slide Time: 21:27)



So here we can see lens alignment and cementing the station, the alignment of lenses takes as little as 4 seconds with the centering accuracy of 2 micro meters.

(Refer Slide Time: 21:50)

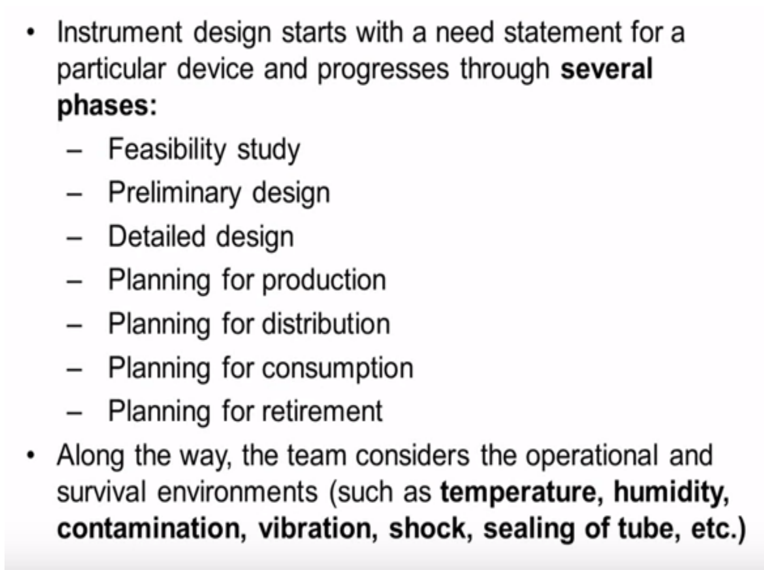


We will start the discussion on complex opto mechanical systems. Opto mechanical design is a sub-discipline of optical engineering in which optical elements such as lenses, mirrors and prisms are integrated into mechanical structures such as cells, housing, trusses, etc., so has to form an optical instrument, so the designing of optical instrument needs a cooperative efforts from different team members, members from lens designers, optical engineers, mechanical Engineers, electrical and electronic engineers, and software engineers.

The input from the various experts in fabrication, assembly, alignment and testing, as well as input from specialists on light sources, detectors, focal plane arrays, electronic systems and pistol signal processing is very essential to build an opto mechanical instrument. When we want to design an optical instrument, we have to consider the manufacturing aspects and design for manufacturing and assembly and design for maintenance of the instrument.

And also, we should consider the economical aspect, so that the instrument becomes easy to handle and then we shall also see esthetic aspects and it should be compact, so that it can be made portable, so when we consider all these aspects, the system becomes very complex.

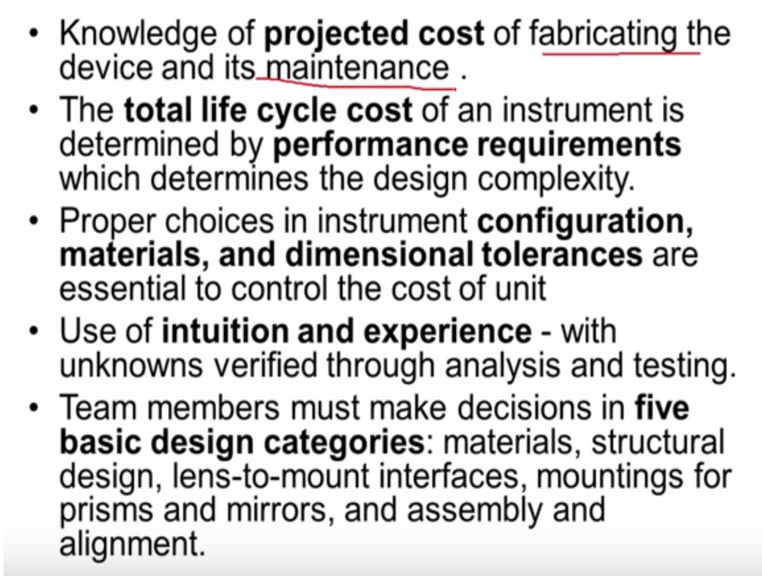
(Refer Slide Time: 23:58)



Now in case of optical instrument design it starts with a need statement for a particular instrument and it undergoes designing several phases such as feasibility study, so we should see whether it is really economically and practically feasible, we should see the preliminary design in which we fix the broader dimensions and then we should go for the detailed design of individual components.

We should plan for production, distribution, consumption and finally, we should plan for retirement of the instrument, so along this way, the team should consider the operational and survival environments that is the working conditions such as temperature, humidity, contamination, whether there are any chances of vibration shock and is it necessary to seal the instruments, so such things one should consider.

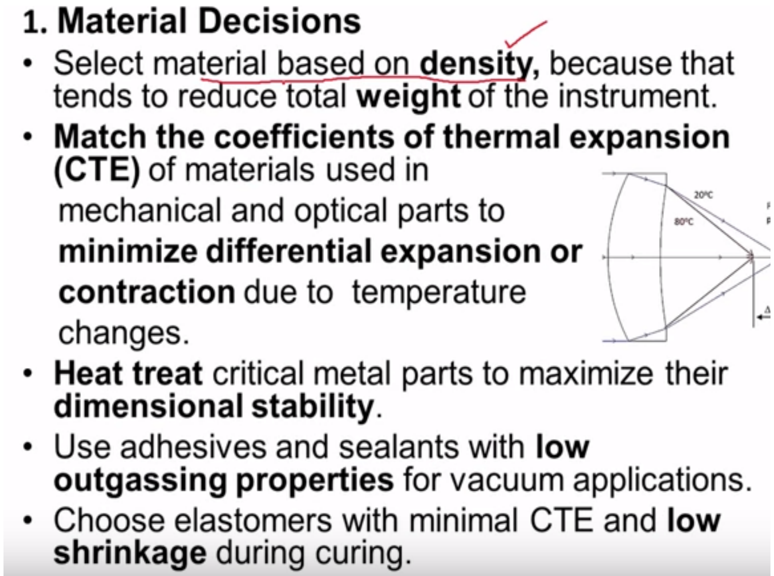
(Refer Slide Time: 25:07)



So knowledge of the cost, projected cost of fabricating the device and how to maintain what is the equipment is cost that also we should consider, what is the total lifecycle cost of the instrument we should properly assist and proper choices with instrument configuration, materials and dimensional tolerances are very essential to control the cost of the instrument and then we should always use the intuition.

And experience with unknowns verified through analysis and testing, and team members must make proper decisions in 5 basic design categories, such as materials aspect, what is the material of optical system, what are the materials used for the mechanical structure and then structural design aspect and then how to mount the lenses, the lens to mount interfaces and then the mountings for prisms and mirrors and how to assemble and how to align the instrument, so in these basic areas, team member should properly decide.

(Refer Slide Time: 26:29)

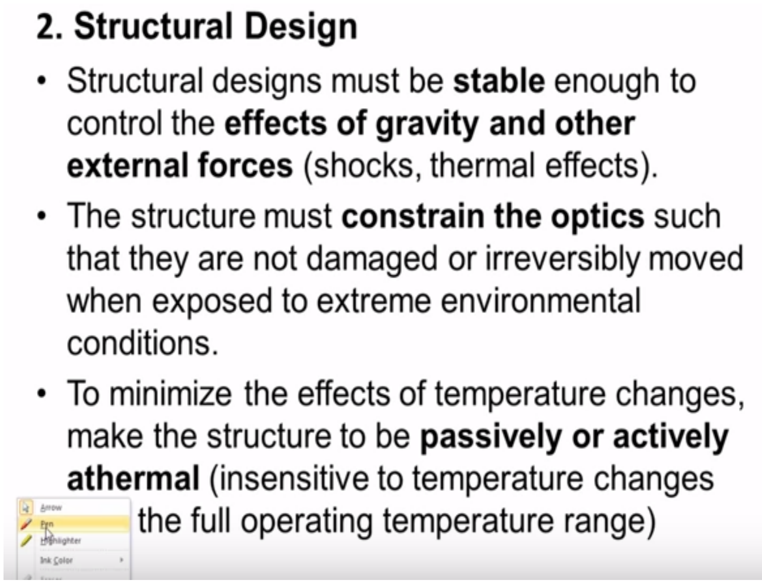


Now we will discuss about the material decisions, so we should select the material based on density because that tends to reduce the total weight of the instrument. We should select the material of barrel and lenses with these weight and then the other important thing is, we should match the coefficient of thermal expansion of materials used in mechanical and optical parts to minimize the differential expansion or contraction due to temperature changes.

So in this diagram you can see how the lens behaves at different temperatures. At 20 degree centigrade, the focal point is at this place and due to the rise in temperature, where the temperature rises to 80 degree centigrade, there is deformation of the lens and the focal point moves nearer to the lens, so because of this, the measure becomes blurred, so the selection of optical materials and mechanical materials is very important to have clear image at 2 different temperatures.

And we should heat treat all the metal parts to maximize the dimensional stability and we should always use adhesives and sealants with low out gassing properties for vacuum applications and choosing elastomers is also very important. We should always choose elastomers with minimal coefficient of thermal expansion and low shrinkage during curing because the shrinkage is more that will lead to internal stresses in the lenses.

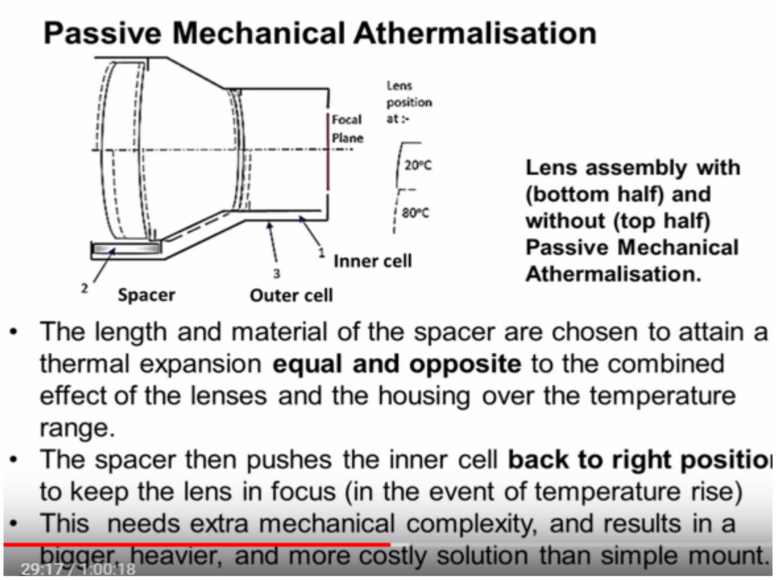
(Refer Slide Time: 28:27)



And then the structural design aspect is a very important thing in designing the opto mechanical systems. The design should be very much stable enough to control the effect of gravity and other external forces such as shocks and thermal effects and then the structure must constrain the optics such that they are not damaged or irreversibly moved when exposed to extreme environmental conditions such as extreme temperatures and very high shocks etc.

And to minimize the effects of temperature changes, we should make this structure to be passively or actively thermal that means structure should become insensitive to temperature such a design should be used.

(Refer Slide Time: 29:17)



And we can see here one example of how we can make the structure passive athermalisation, so this diagram shows cell, the barrel mechanical structure with lens. The top of the picture is not made passive athermalisation that is normal structure, so we can see 2 working temperatures 20 degree and 80 degree centigrade, so when the temperature raises, there is expansion of lenses and structure and because of that lens moves towards in the left direction and then image becomes blurred.

Now how we can make this passive athermalisation, we can see here, there is a spacer, the length and material of the spacer are so chosen that the spacer attains a thermal expansion equal and opposite to the combined effect of the lenses and housing over the temperature range. Now when the temperature increase, we can see the passive athermalisation structure has an external cell and inside there is inner cell and then there is a spacer, and the lens is mounted on the inner cell.

When the temperature rises the spacer expands in the opposite direction, so the spacer pushes the inner cell back to the right push. This spacer pushes the inner cell back to the right position, so the effect of thermal expansion or contraction is nullified, so this way we can make the structure passive athermalisation, so this needs extra mechanical complexity that means we have to provide a inner cell and then spacer, so this results in a bigger and heavier and more costly solution than simple mount.

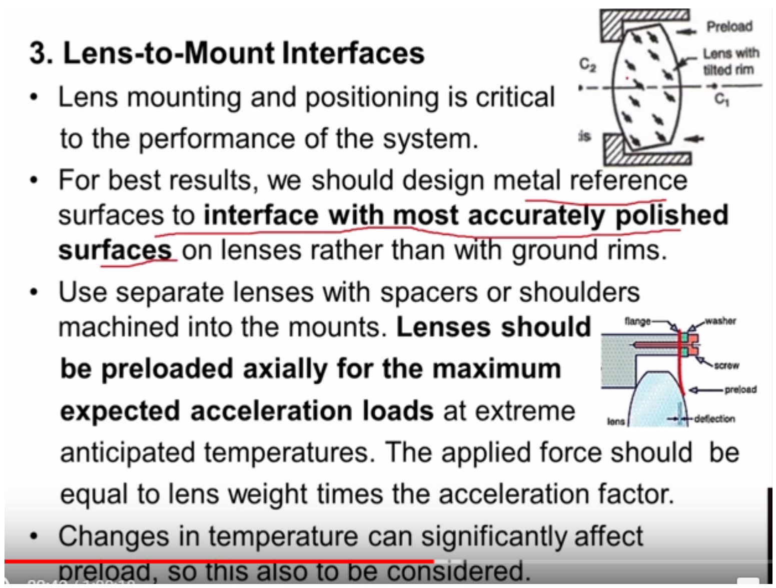
(Refer Slide Time: 31:36)

- Select proper **lens material** for athermalisation (Germanium , Zinc Selenide, Zinc Sulphide)
- To maximize performance without excessively tight tolerances on dimensions, design a carefully **optimized number of mechanical adjustments** into the instrument
- Design structures for maximum possible **stiffness** within weight and packaging constraints to reduce deflections from external forces such as gravity.
- Isolate the supported optical components from mechanical **resonance effects** under vibration conditions.

Now we should always select proper lens material for athermalisation that means normally Germanium, zinc selenide, and zinc sulphide can be used to maximize performance without excessively tight tolerances on dimensions, we can design a carefully optimized number of mechanical adjustments into the instrument and design structure should have maximum stiffness within the weight and packaging constraints to reduce deflection from external forces such as gravity.

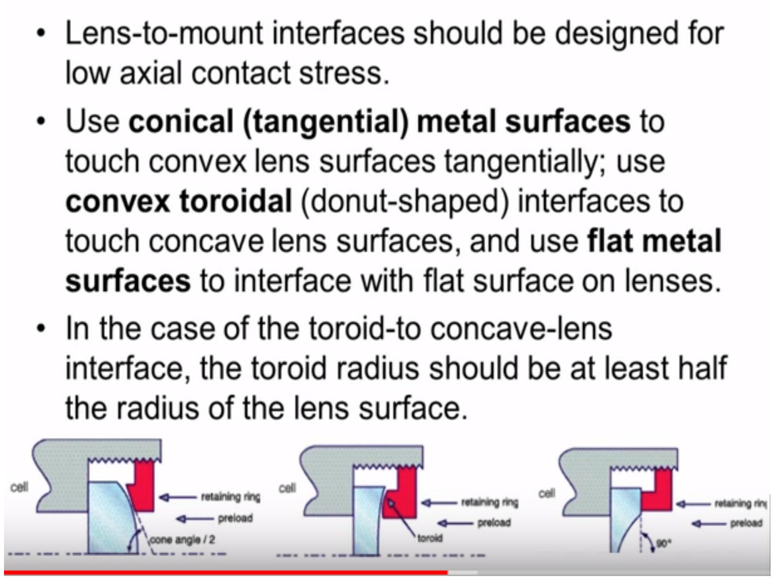
And we should always isolate the supported optical components from mechanical response effects under vibration conditions. Proper lens to mount the interfaces should be used while assembling lenses in the barrel.

(Refer Slide Time: 32:40)



For best results, we should design the metal reference surfaces to interface with most accurately polished surfaces, we can observe here that this is the optical surface and is another optical surface which are made more accurately than the rim of the lens, so we should use the optical surface for mounting purpose and provision should be made for freeloading the lenses, lenses should be pre-loaded axially for maximum expected acceleration loads at extreme anticipated temperatures.

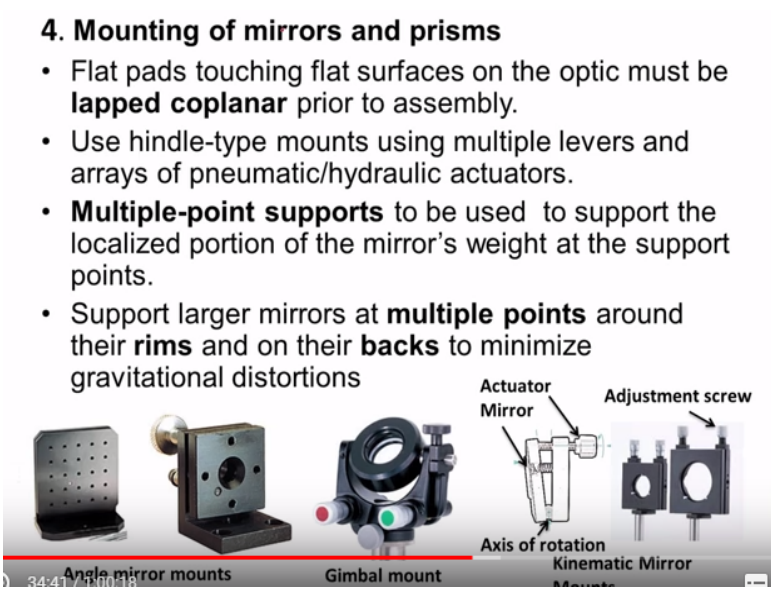
(Refer Slide Time: 33:38)



There are chances that preload changes with temperature, so this point also should be considered and always we should avoid over preloading or since it will cause the contact stress. Lens to mount interfaces should be designed for low axial contact stress and we should use appropriate arrangement for interface of retaining a ring with the lens, conical metal surface can be used to touch convex lens surface tangentially.

As shown here or we can use convex toroidal interfaces to touch concave lens surface as shown here and we can use flat metal surfaces to interface with flat surface and lenses as shown in this picture.

(Refer Slide Time: 34:41)

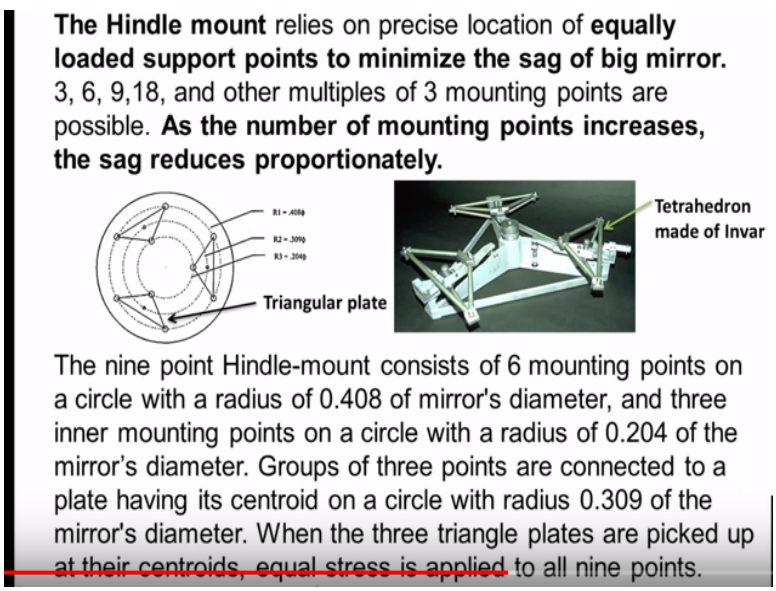


Mounting of mirrors and prisms is also very important when we design the optical system, flat bed pads, flat pads touching flat surfaces of the optic must be lapped coplanar prior to assembly proper lapping should be made, so that contact is good. We should use hindle type mounts using the multiple levers and arrays of pneumatic and hydraulic actuators to support large mirrors, multiple point support should be used to support the localized portion of the mirror's weight at support points.

We should support larger mirrors at multiple points around their rings and their backs to minimize the gravitational distortion that means the mirror should support large mirror should be supported at multiple points on the surface and also support should be given at rims. We can see the different mounting arrangements for mirrors, angle mirror mounts, so we have adjusting screw for adjusting the angle of mirror the Gimbal mounting is also possible.

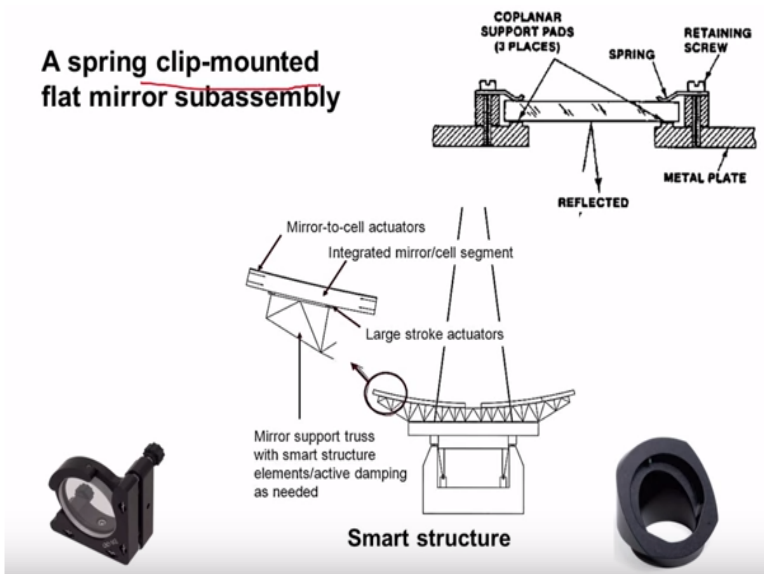
Micrometers are provided for final judgment to the angle of mirror and here you can see the kinematic mirror mounts, so this is the actuator or screw. By rotating this, the angle of the mirror can be changed.

(Refer Slide Time: 36:32)



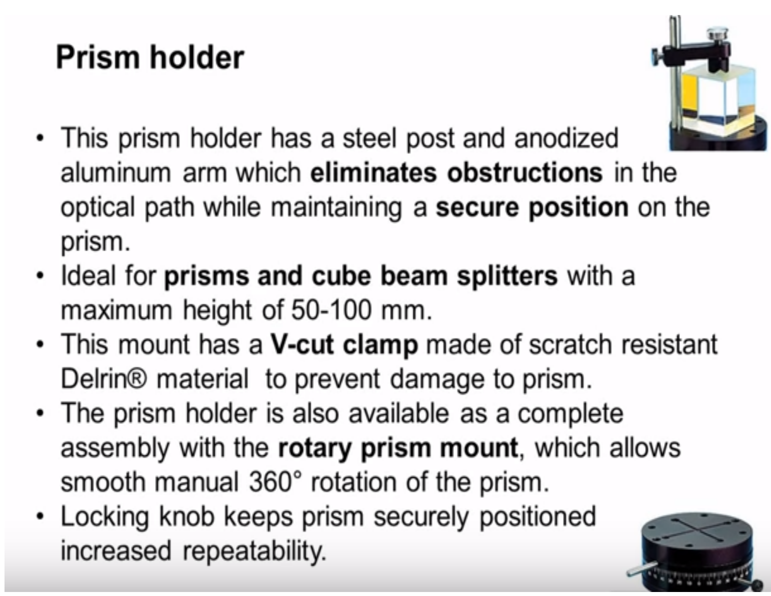
Now this picture shows the Hindle mount, now multiple support points are available, you can see the triangular plates, each triangular plate has 3 supporting points, so large mirrors can be supported by using the engine mount as shown here, we can see a photographic view of the Hindle mount, so tetrahedron are there, are made of Invar to have the integral structure.

(Refer Slide Time: 37:15)



So here, we can see spring clip mounted flat mirror sub-assembly, we can see the coplanar support parts here, so depending upon the size of the mirror, multiple supporting can be made and this is 45 degree mirror adapter and this is a kinematic mirror mount, so we can see the actuator for adjusting the inclination. We can also have smart structure to support very big mirrors, so you can see here supporting points, active damping can be used to support the big mirrors.

(Refer Slide Time: 38:06)



We should use appropriate prism folders, you can see the prism mounted on a flat surface and there is a vertical pillar and there is a clamp, we can see the V-cut clamp here made of scratch resistant Delrin material, so because of this, the damage to the prism is prevented using this clamp, the prism properly and we can also have rotary prism mount, which allows smooth manual 360 degree rotation of the prism by operating this rotary device, we can change the inclination.

(Refer Slide Time: 38:56)

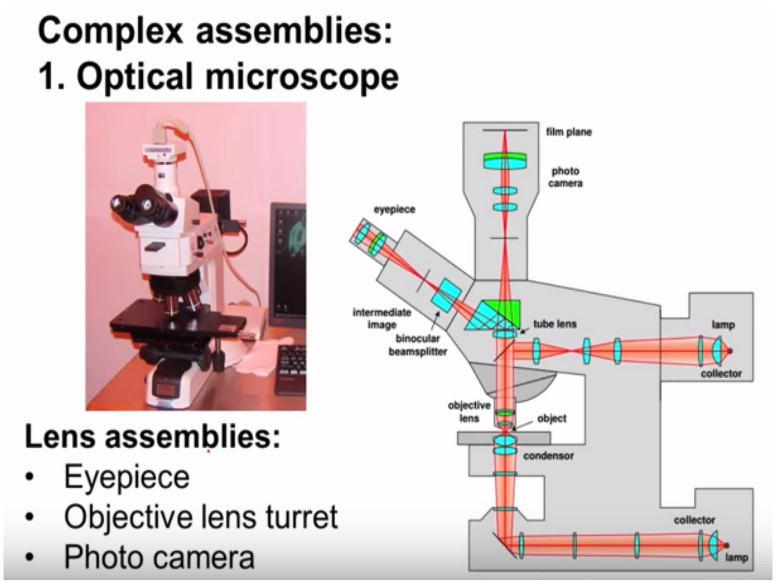
5. Assembly and alignment

- Start assembly by **cleaning** all parts thoroughly. Carry out the assembly process in a **clean, dry environment.**
- Use only **approved lubricants** and apply them carefully to **avoid contamination**.
- For multiple-lens assemblies, rotate the lenses and make adjustments so that **axis of lenses coincides with cell axis**
- **Adjustments should be locked** after the optics are aligned; by mechanical clamping, epoxy pinning, laser welding, or by soldering.
- **Seal optical instruments** during assembly to protect optics from moisture and particulates. They can be purged with dry N_2 or He.

The 5th important design decision is about assembly and alignment of optics inside the mechanical structure. We should clean all the parts, all the optical parts and mechanical parts thermally and then we should carry out the assembly process in a very clean and dry environment. We should always use approved lubricants and we should apply them very carefully to avoid contamination and for multiple lens assemblies, we should rotate the lenses and make adjustments, so that axis of lenses coincides with axis.

We can always go for a manual lens assembling process or we can use automated alignment stations if necessary and then adjustment should be locked after the optics are aligned by means of mechanical clamping or epoxy pinning or laser welding or by soldering, so that the position of optics is fixed, so we should seal the optical instruments after the assembly is over to protect optics from moisture and particulates. We can always purge the instrument with dry nitrogen or helium.

(Refer Slide Time: 40:35)

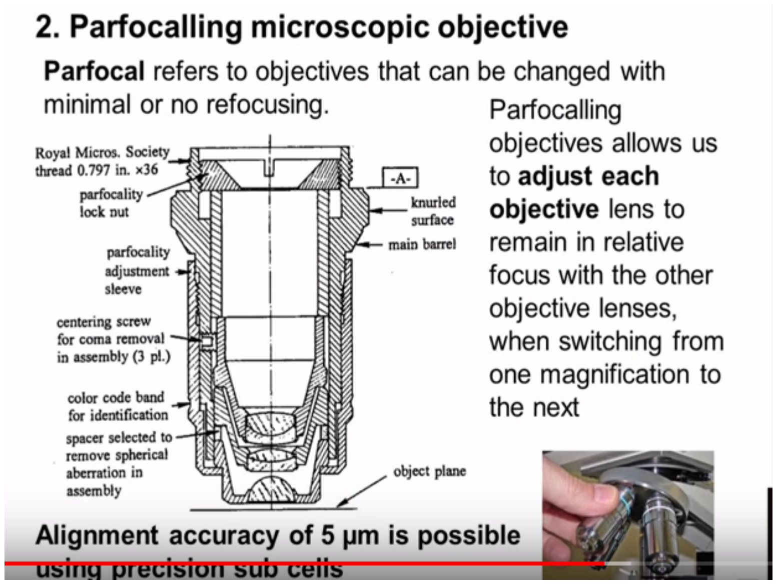


Now let now see some complex up to mechanical assemblies, so we have optical microscope, the external appearance of the optical microscope is shown here, so we have the mechanical structure, the C shaped structure, which supports all the other optic elements. We have stage on which a work piece to be inspected can be placed. We have various screws for adjustment for focusing of the work piece and then we have a turret, objective turret.

So different objective lenses are provided on the turret, so depending upon the application, we can select appropriate objective lens with required magnification and then we have eye piece sub-assembly and then there is a camera attachment, so this is photo camera attachment and then we have another sub-assembly that is light source sub-assembly. We have a light source for surface elimination and we have another light source for contour elimination.

Now all these sub assemblies are carefully aligned and assembled and then each sub assembly is mounted on this C shaped body by taking proper care, so that we can have accurate image of the work piece and we can inspect the work piece easily.

(Refer Slide Time: 42:43)



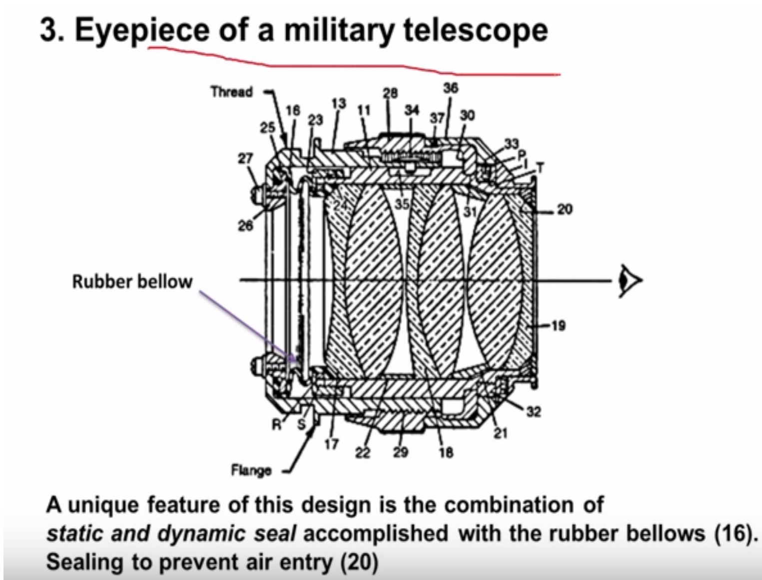
Now we have another opto mechanical assembly here, this is parfocalling microscopic objective. Now, parfocalling it refers to the objectives that can be changed with minimal or no refocusing, now parfocalling objectives allows us to adjust each objective lens to remain in relative focus with other objective lenses when switching from one magnification to the other magnification. We can see here we have a direct assembly on which multiple objective sub-assemblies are mounted.

So if we have parfocalling microscopic objective, when we change the objective to get different magnification, we need not have to do the refocusing, here you can see a very complex nature of the mechanical structure. We have the knurled surface on this structure, we can see here the knurled surface and then we have the main barrel in which the lenses assembly is mounted and then we have parfocallity adjustment sleeve by adjusting this sleeve.

We can make the objective parfocalling and then we can see the lens assembly here. We have doublets and we have another doublet and we have convex surface lens here and then we have centering screw for removal in the assembly by operating this, we can remove the coma and then we have a spacer here, so this spacer is selected to remove spherical aberration in the assembly.

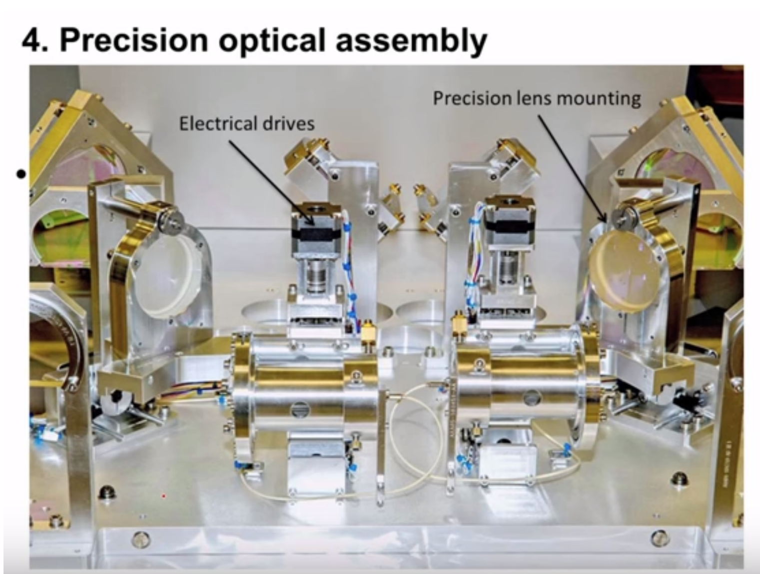
It means properly spacer is chosen to remove aberration and then we can see a parfocallity lock nut after adjusting the sleeve to have proper focusing, this lock nut is used to lock the sleeve in its position. Now alignment accuracy of this objective is 5 micron alignment accuracy is possible.

(Refer Slide Time: 45:34)



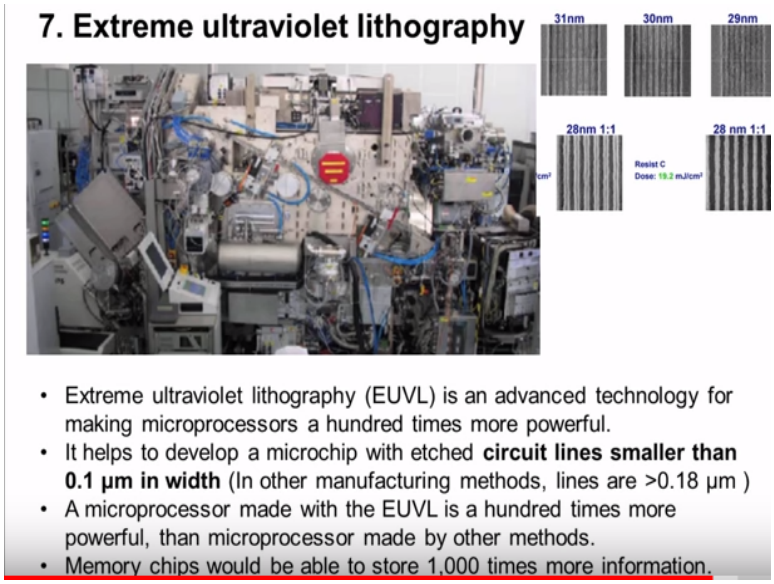
Now we have another eye piece of a military telescope, we can the cemented lenses, lens doublet, all the 3 are lens doublets, they are properly aligned, optical axes are aligned and then they are cemented and then they are placed in the mechanical structure. The unique feature of this design is use of rubber bellow that is static and dynamic seal is accomplished with a rubber bellow here and the tube is sealed to prevent air entry.

(Refer Slide Time: 46:25)



So in this precision optical assembly, we can see precision lens mounting, you can see the arrangement, how the lenses are mounted and the mounting of precisely machined lenses in the lens mounts and then you can also see the electrical drives for making the adjustment in optical elements and mechanical elements.

(Refer Slide Time: 48:02)



In this we can see lithography projection lens system, we can see a very complex nature of the lens assembly, some lenses are cemented and some individual lenses are mounted in the mechanical structure, we can see the plano concave and other types of lenses properly aligned axially, as well as radially. We can make the electronic circuits with very precise features and feature sizes of as small as 250 nanometers can be made with this lithography projection lens assembly.

And we have another important system here, this is extreme ultraviolet lithography system EUV lithography system, so this lithography system is an advanced technology for making microprocessors, hundred times more powerful, so this system helps to develop a microchip with etched circuit lines smaller than 0.1 micrometer in width, in other manufacturing methods, line bits of greater than 180 nanometers are possible.

Whereas, in this system, the circuit line width can be as low as 100 nanometer or even lesser than 100 nanometer we can see here in these pictures, we have lines circuit lines, which are smaller than 100 nanometer that is 31 nanometer, 29 nanometer line width, 28 nanometer line widths are possible with this sophisticated system. A microprocessor made with this technology is hundred times more powerful than microprocessor made by other methods.

Memory chips would be able to store thousand times more information if they are made by this technology. We can see a very complex nature of opto mechanical system here.

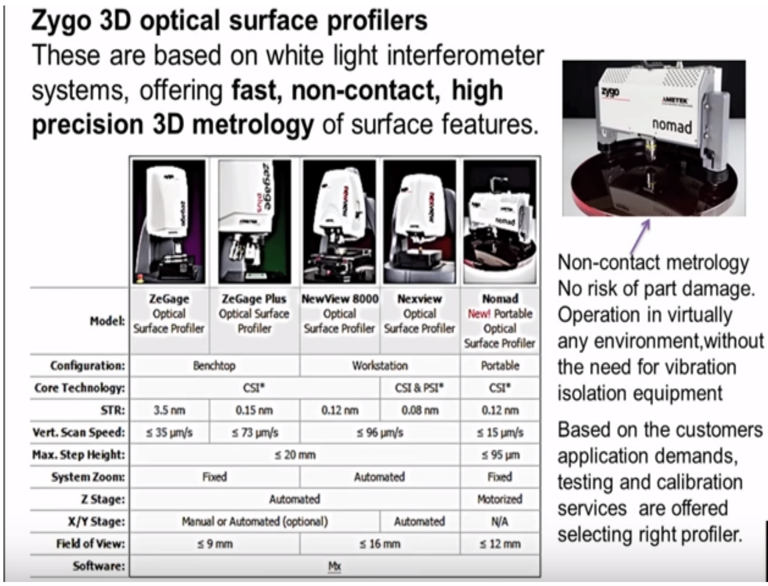
(Refer Slide Time: 49:47)

Now let us discuss on testing and certification services, many organizations are available throughout the world offering testing and certification services related to metrology. The tests, the various components, precision components are traceable to NIST standards and they are also offering calibration services, they calibrate various metallurgical instruments according to international standards and they assure calibration certificates.

So one such organization is Zygo testing and Zygo Corporation offering testing and certification services throughout the world, they have many centers with testing facilities. Zygo corporation specializes in optical metrological systems, Zygo metrology systems are based on optical interferometry measuring displacement surface figure and optical wavefront. The state-of-the-art equipment for testing the following parameters are available with Zygo.

Roughness measurement of precision surfaces, air bearing surface, geometry of magnetic heads, optical components and systems such as flats, spheres and prisms can be tested, reflective and anti-reflective coating facility and testing facility, surface angle measurement and an absolute calibration of spheres and flats, as well as large aperture plano surfaces is possible with the testing facility available with Zygo.

(Refer Slide Time: 51:58)



Model:	ZeGage Optical Surface Profiler	ZeGage Plus Optical Surface Profiler	NewView 8000 Optical Surface Profiler	Nexview Optical Surface Profiler	Nomad New! Portable Optical Surface Profiler
Configuration:	Benchtop		Workstation		Portable
Core Technology:	CSI*			CSI & PSI*	CSI*
STR:	3.5 nm	0.15 nm	0.12 nm	0.08 nm	0.12 nm
Vert. Scan Speed:	≤ 35 µm/s	≤ 73 µm/s	≤ 96 µm/s		≤ 15 µm/s
Max. Step Height:	≤ 20 mm				≤ 95 µm
System Zoom:	Fixed		Automated		Fixed
Z Stage:	Automated				Motorized
X/Y Stage:	Manual or Automated (optional)			Automated	N/A
Field of View:	≤ 9 mm		≤ 16 mm		≤ 12 mm
Software:	Mx				

Now here we can see Zygo 3D optical surface profiler, they have different facilities 3D optical surface measurement facility based on white light interferometer systems offering fast non-contact high-precision 3D metrology of surface features, so different surface profilers are produced and used by Zygo for testing purpose with different configurations like bench-type configuration, workstation configuration, and portable configuration.

These profilers have surface topography repeatability of 3.5 nanometers and 0.15 nanometers and 0.018 nanometers such a fine repeatability these instruments have and they have XY stage automated XY stage fixed to the profilers and then vertical scan speed varies from 15 micrometer per second up to 96 micrometers per second. Based on the customers application demands, testing and calibration services are offered selecting the appropriate profilers.

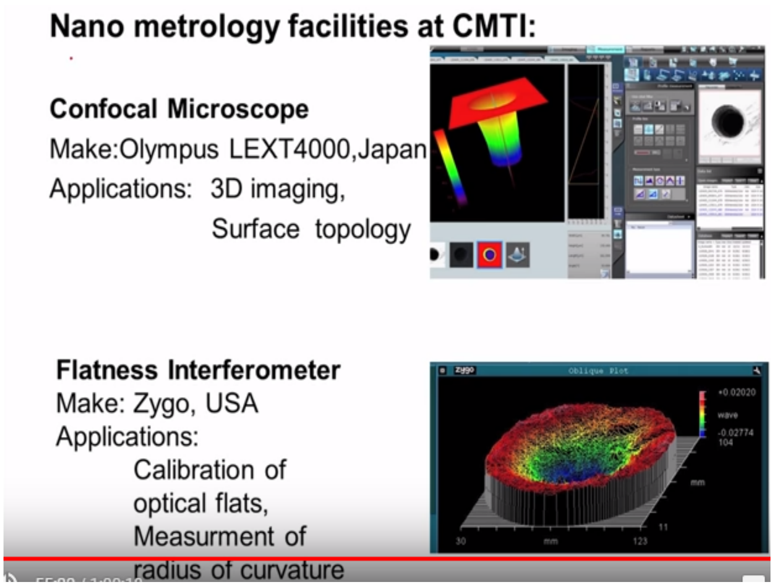
All these profilers are non-contact profilers, so these profilers can be directly mounted on work pieces since they use non-contact technology there is no risk of part damage, operation in virtually any environment without the need for vibration isolation is possible.

(Refer Slide Time: 54:09)

Another important organization offering testing and certification services is central manufacturing technology Institute situated at Bengaluru the metrology laboratory attached to CMTI is accredited by the National Accreditation Board for laboratories and is equipped with precision calibrating equipment in precisely controlled environmental conditions. Services offered by this laboratory are mentioned here.

Calibration of gauges and measuring instruments with traceability to international standards and then dimensional form and surface finish measurements of components, supply of high precision grade granite surface plates and straight edges, calibration and supply of reference masters like appreciation spheres, roughness masters and master cylinders.

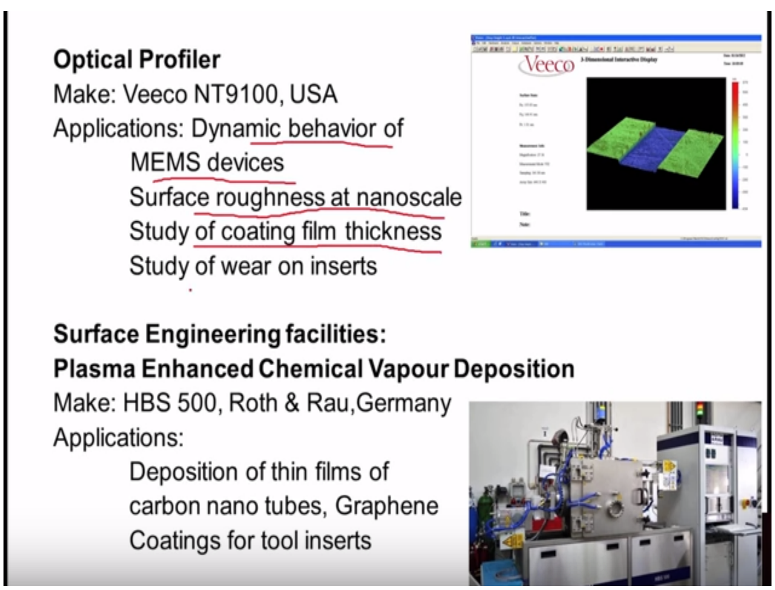
(Refer Slide Time: 55:20)



The CMTI has a very good nano metrology facilities they have confocal microscopy for 3D imaging and surface topology studies. They have flatness interferometer, which can be used for calibration of optical flats and measurement of radius of curvature of optical lenses. A ultra precision coordinate measuring machine is available with CMTI, which can be used for dimensional measurements of very complex micro components.

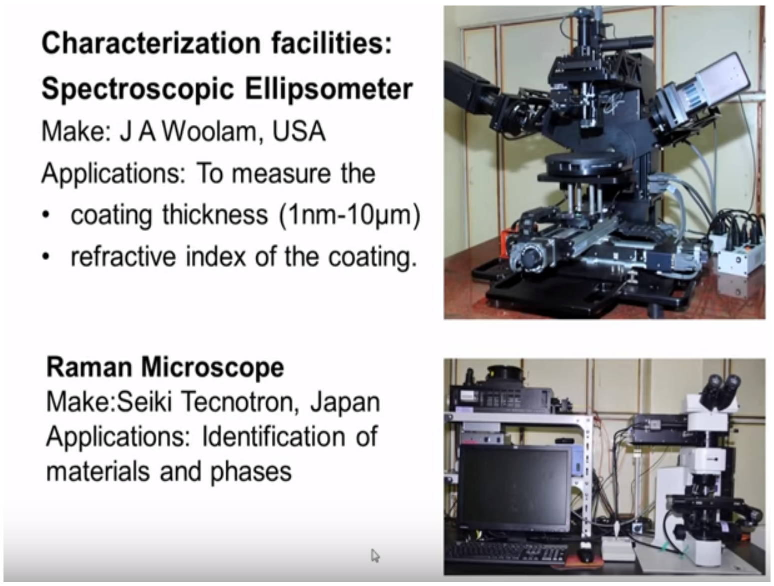
And also for tactile and optical probing system A gauge block interferometry is also available with the CMTI, which can be used for calibration of slip gauges to an accuracy of 20 nanometers.

(Refer Slide Time: 56:32)



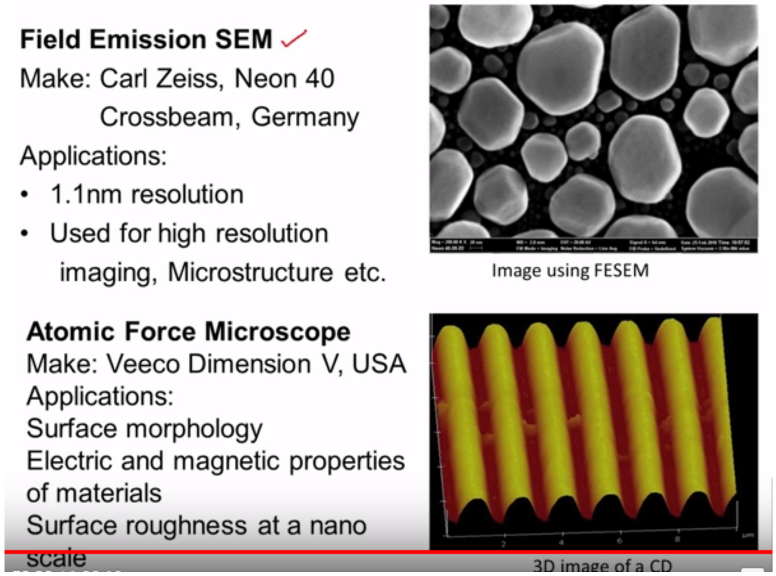
CMTI has an optical profiler, which can be used to study the dynamic behaviour of MEMS devices and to study the surface, measure the surface roughness at nanoscale, study of coating film thickness and study of wear on inserts. They have plasma enhanced chemical vapour deposition system, which can be used to deposit thin films of carbon nano tubes and Graphene on surfaces and for the application of coatings for tool inserts.

(Refer Slide Time: 57:18)



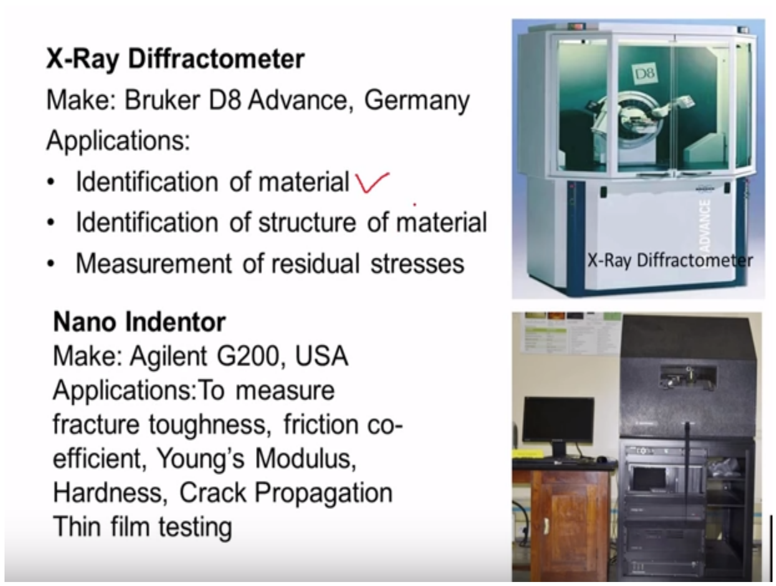
And then they have very good characterization facilities such as spectroscopic ellipsometer, which can be used to measure the coating thickness, the range of 1 nanometer to 10 micrometer and it can be used to measure the refractive index of the coated surface and then there is Raman microscope, which can be used for identification of materials and phases.

(Refer Slide Time: 57:57)



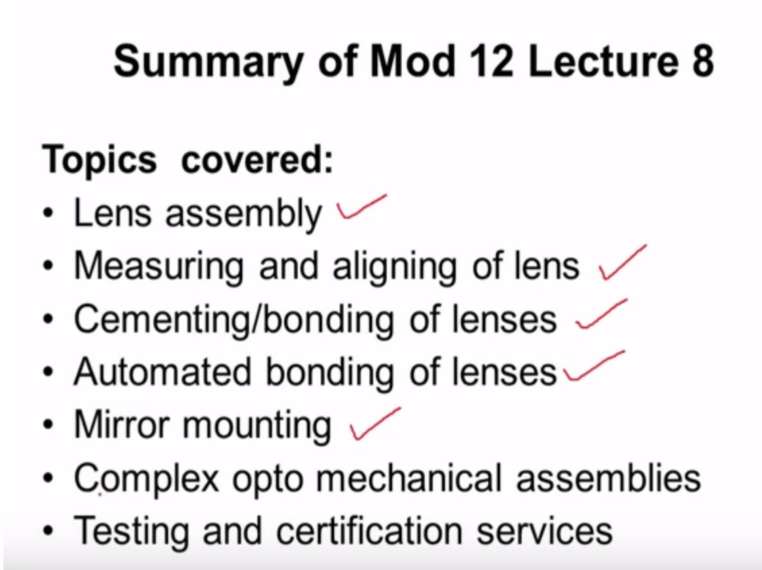
Field emission scanning electron microscopy is also available with CMTI with a resolution of 1.1 nanometer and this can be used for high resolution imaging and micro structural studies, atomic force microscope is also available, which can be used for surface morphological studies and to measure the electric and magnetic properties of materials and for the measurement of surface roughness at nano scale.

(Refer Slide Time: 58:41)



X-ray diffractometer is also available, which can be used for identification of material, identification of structure of materials and for measurement of residual stresses. Nano indenter is also available, which can be used to measure the fracture toughness, friction coefficient, Young modulus of materials, hardness of materials, crack propagation and thin film testing.

(Refer Slide Time: 59:12)



Now let us summarize the module 12, lecture number 8, in this lecture we discussed about lens assembly, measuring and aligning of lenses and optical systems, cementing and bonding of lenses, automated bonding of lenses, and then how to mount mirror in opto mechanical systems and then we discussed about some of the complex opto mechanical assemblies like lithography systems.

And then we also discussed about testing and certification services offered by many organizations throughout the world related to the metrology, with this we will stop this lecture. Thank you.