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The adjustment mechanisms: types and their applications in optical systems

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ABSTRACT

The various optical elements in a sophisticated optical system must be precisely aligned to each other to obtain an aberration-free image. In optical systems with very tight alignment tolerance requirements, the optics and their mounts are usually manufactured to rather loose tolerances, and adjustment mechanisms are then used to align the optics relative to each other at assembly. Another class of adjustment mechanisms is employed to move one or more optical elements of a system in real time to compensate for the image degradation due to environmental effects. This paper discusses the three basic types of adjustment mechanisms namely: linear, rotary and tilt mechanisms. Each mechanism consists of a number of parts such as the actuator, locking and preloading components. The selection criteria for these components of the adjustment mechanisms are presented in detail. Finally, some design guidelines for applications of the adjustment mechanisms in complex optical systems are presented.

1. INTRODUCTION

Certain optical systems, such as those for submicron lithography, can have 10-15 mirrors and lenses that must be axially positioned relative to each other and centered on a common optical axis within tolerances of a few microns. In order to achieve these positioning accuracies, it is impractical and extremely cost prohibitive to manufacture the optics and its mounts to micron-level machining accuracies. For such optical systems, it is more practical and economical to fabricate the optics and the mounting hardware to rather loose tolerances, and provide adjustment mechanisms to align the optical elements relative to each other at the time of assembly. This class of adjustment mechanisms are designed for infrequent use and generally have manual actuators. Once the optical system has been aligned, these adjustments are locked in place to retain the alignment.

Another class of adjustment mechanisms are employed to move or tilt an optical element in real time to compensate for the degradation of the image quality due to environmental effects. These mechanisms have motorized actuators and position readout sensors operating in a closed loop control system. Such mechanisms are generally used to correct focus and magnification errors in the optical systems due to thermal effects or any other environmental degradations.

2. TYPES OF ADJUSTMENT MECHANISMS

The three basic type of adjustment mechanisms are linear, tilt and rotary adjustments. A rigid body in space has six degrees of freedom, which are the three translations and the three rotations about x, y and z axes. An optical element in a system may need one or more of these translation or rotary adjustments for alignment purposes. In order to avoid cross-coupling between different adjustments, the preferable approach is to stack single axis adjustments on top of each other to achieve a multiple type of adjustment.

A typical adjustment mechanism consists of five basic components. These are:

1. An *interface* between the moving optical element and the fixed structure.

2. An *actuator* to adjust the moving element relative to the fixed structure.

3. A *coupling* between the actuator and the moving element.

4. A *preloading device* to eliminate backlash in the mechanism.

5. A l*ocking mechanism* to retain the adjusted position.

For each of these five components, a number of choices are available to the designer depending on the type of adjustment mechanism. The most commonly used components for linear, rotary, and tilt mechanisms are shown in table 1, table 2 and table 3 respectively.

3. SELECTION CRITERIA FOR COMPONENTS OF LINEAR ADJUSTMENT MECHANISMS

It is clear from the tables that a designer has a wide choice in selection of the components for a particular type of mechanism. The selection of a particular type of component is dictated by the performance requirements such as the frequency, range and resolution of adjustment, and other factors such as the size, cost and the load capacity of the mechanism. In the following sections, a number of options for different parts of an adjustment mechanism are discussed, and general guidelines are presented to help the designer in selecting suitable components for a particular application.

3.1 *The interfaces*

The interface between the moving optical element and the fixed mounting structure is generally determined by such design factors as the travel range and frequency of adjustment, shock, load capacity, cost and size

Table 1. Choice of components for linear mechanisms

Interface	*Actuator*	*Pre-load*	*Locking*	*Coupling*
Flexure	Coarse screw	Compression spring	Set screw	Ball /cone
Kinematic	Fine screw	Extension spring	Jack screw	Ball/flat
Ball bearing	Micrometer	Flat spring	Lock nut	Ball/socket
Roller bearing	Differential micrometer	Belleville washer	V clamp	Threads
Air Bearing	DC motor	Curved washer	Collar clamp	Flexible coupling
Dovetail Slide	Stepper motor		Epoxy	Lead screw
Flat slide	Piezoelectric		Control system	

Table 2. Choice of components for rotary mechanisms

Interface	*Actuator*	*Pre-load*	*Locking*	*Coupling*
Cross flexure	Coarse screw	Compression spring	Set screw	Ball /cone
Ball bearing	Fine screw	Extension spring	Lock nut	Ball/flat
Spherical bearing	Micrometer	Flat spring	V clamp	Ball/socket
Journal bearing	Differential micrometer	Belleville washer	Collar clamp	Flexible coupling
Roller bearing	DC motor	Curved washer	Epoxy	Worm/gear
Air bearing	Stepper motor	Torsion spring	Control system	Rack/pinion
	Piezoelectric			Belt/pulley

Table 3. Choice of components for tilt mechanisms

Interface	*Actuator*	*Pre-load*	*Locking*	*Coupling*
Cross flexure	Coarse screw	Compression spring	Set screw	Ball /cone
Kinematic	Fine screw	Extension spring	Jack screw	Ball/flat
Spherical bearing	Micrometer	Flat spring	Lock nut	Ball/socket
Journal bearing	Differential micrometer	Belleville washer	V clamp	
Blade flexure	DC motor	Curved washer	Collar clamp	
	Stepper motor		Epoxy	
	Piezoelectric		Control system	

requirements. If a long travel range is required and the mechanism is going to be adjusted frequently, a bearing interface must be used between the moving element and the fixed structure. Ball and roller slides, shown in figures 1 and 2, have low friction and are suitable for long travel ranges. Ball slides are less expensive than roller slides, but also have lower load capacity and accuracy (straightness of travel) as compared to roller slides. A dovetail slide, shown in figure 3, has high stiffness and load capacity and has a low cost. The main disadvantages of a dovetail slide are stiction and high friction. These slides are generally used in prototypes for laboratory type setups, where the adjustments have to be simple and economical.

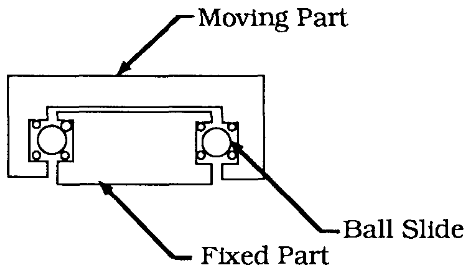

Figure 1. A typical ball slide interface for linear mechanisms

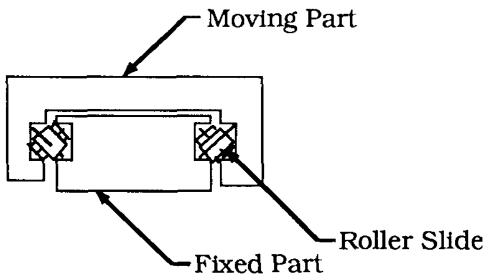

Figure 2. A typical roller slide interface for linear mechanisms

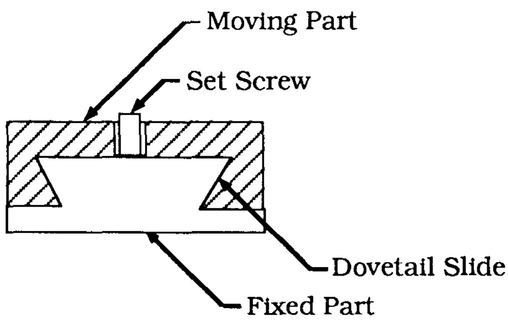

Figure 3. A typical dovetail slide interface with set screw locking

Hydrostatic bearings, which include both gas and oil bearings, are virtually free of friction and wear and have negligible cross-axis run out. In optical systems, oil bearings are not commonly used because these are messy and present the risk of contaminating the optics. The optical system that require adjustment mechanisms with a long travel range and high accuracy and load capacity use gas bearings such as shown in figure 4. The pressurized gas is generally very clean and dehumidified air but some applications use dry nitrogen or helium also. The main disadvantages of gas bearings are their cost and complexity. A remote and elaborate pumping and filteration system is required to supply clean and dry air. The design and fabrication of gas bearings is complex and expensive. The number and size of air jets, size of the air relief pocket and surface area of the bearing, and supply pressure of the air must all be taken into account when designing an air bearing for an application.

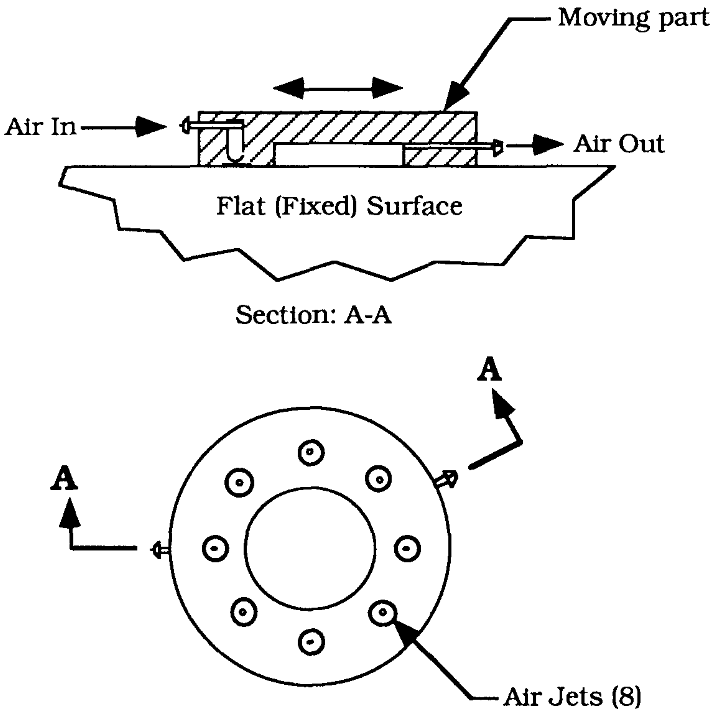

Figure 4. An air bearing interface for linear mechanisms

Flexures are suitable for backlash free adjustments over short travel ranges. These have low friction and hysteresis, and do not require any type of lubrication. Flexures can have several shapes such as a flat strip, circular or universal. A flat flexure interface is shown in figure 5. The design and fabrication of flexures is quite complex and is discussed in detail in by Billing, Weinstein, Paros and Weisbord[1]. For an application, a flexure must be designed to have a specific stiffness which is determined by its length, width , thickness, shape and material. When flexures are bent to move a component, a reaction force is induced in the component attached to the flexure. In applications where flexures are directly bonded to optical components, the reaction force from the flexure can produce localized surface distortion. Therefore, the flexures must be designed for a proper stiffness to keep this distortion within acceptable limits. The flexure interface is generally suitable for those precision mechanisms which require high resolution over short travels.

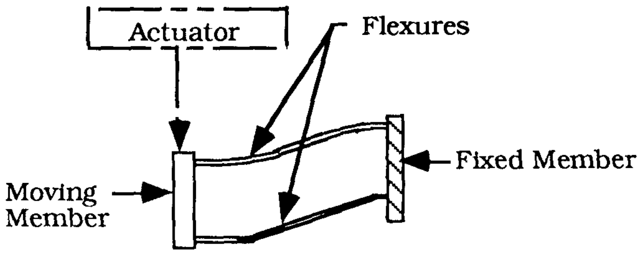

Figure 5. A flat flexure interface for linear mechanisms

For low cost and light loads, a sliding contact between the the moving and fixed part, shown in figure 6, may be the best alternative. This type of interface has high friction and there is no control over the linearity of the adjustment i.e. a linear translation may be accompanied by a slight in plane rotation. This type of sliding interface is suitable for infrequent adjustments.

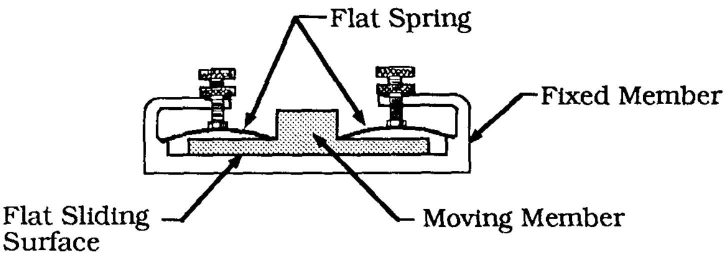

Figure 6. A linear mechanism with a flat sliding interface

3.2 *The actuators*

The choice of a suitable actuator depends on travel speed, range, resolution and frequency of adjustment, and cost, size and weight requirements for the adjustment mechanism. For example, the motorized actuators are generally used for making frequent adjustments in real time. These include DC, linear and stepper motors and piezoelectric devices. The main advantages of such actuators are long travel range, high resolution and velocity, and position readout capability. These actuators can come with built in position encoders and can be used in a closed loop control system. Therefore, the position of an optical component can be monitored, and the drifts due to environmental effects can be corrected in real time. The principle disadvantages of motorized actuators are their high cost and weight and large size.

A piezoelectric actuator is used for short travel range requiring high resolution. A high voltage is needed to produce a movement of the order of a few microns. The piezo actuators have high load capacity. Typical disadvantages are hysteresis, creep and nonlinearity of travel versus the applied voltage.

If an application does not require frequent adjustments, it is more cost effective to use screws or micrometers. If a position readout is not required, the screws, as shown in figure 7, are more economical and compact as compared to micrometers. The screws can be coarse, fine or of differential type depending on the resolution requirements. The differential screws and micrometers are used for small travels, and are quite bulky and more expensive as compared to regular screws.

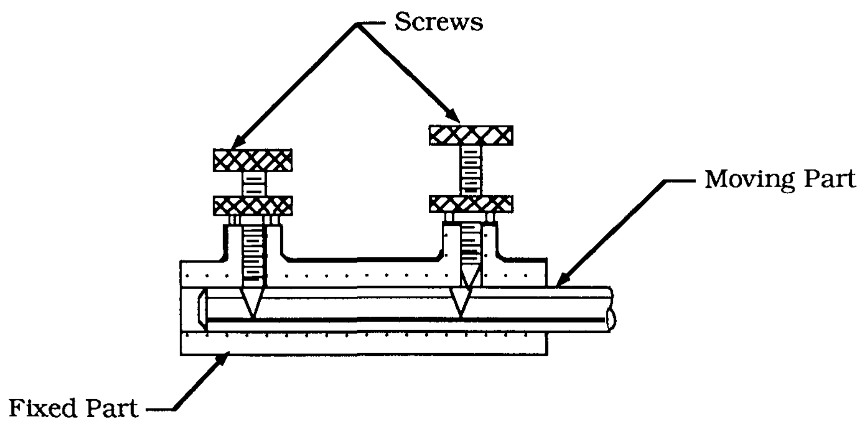

Figure 7. A linear mechanism with screw actuators

3.3 *The coupling methods*

A number of options are available to couple the actuator to the moving component of an adjustment mechanism. The choice of a suitable method depends on such design factors as frequency of adjustment, shock requirements, weight, cost and size of the mechanism. The tip of the actuator is generally rounded and polished to a high finish to minimize wear due to friction. The tip of the actuator can bear against a flat surface, a cone or a spherical socket. The flat surface, shown in figure 8, results in a point contact with the tip of an actuator and therefore, produces high contact stresses. The ball/cone interface, shown in figure 9, results in a line contact, and produces much lower contact stresses. For infrequent adjustments of light weight components, a ball tip acting directly against a flat surface, is the most simple and economical choice. The ball cone interface is more expensive to machine and larger in size, and is generally used for adjusting heavy components which must be adjusted frequently.

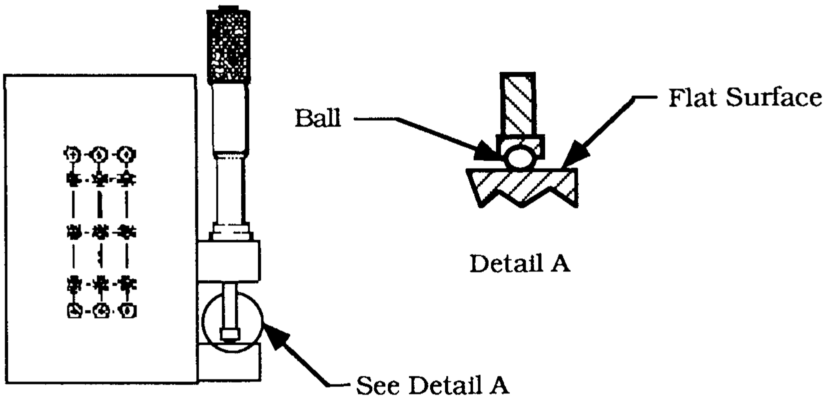

Figure 8. A translation stage with a micrometer and a ball/flat coupling

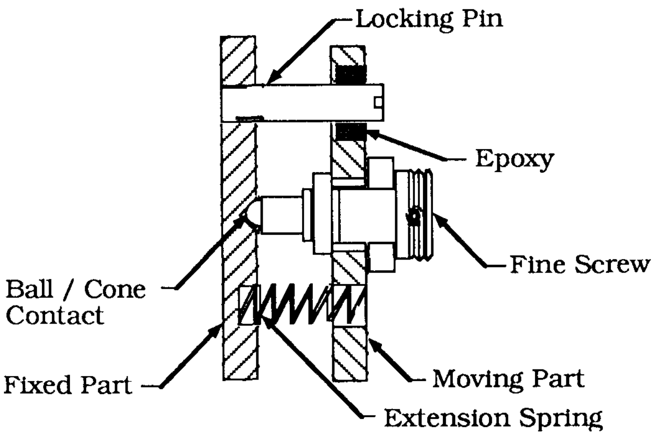

Figure 9. A linear mechanism with a ball/cone interface, epoxy locking and extension spring preloading

The moving component can also be physically attached to the actuator through a threaded attachment or through a flexible type of coupling. The threaded coupling, shown in figure 10, is not commonly used because a slight misalignment of the line of travel relative to the actuator axis induces lateral loads in the actuator and can cause rapid wear and damage to the actuator. The flexible coupling, shown in figure 11, does not have this problem because slight misalignments are compensated by the flexibility of the coupling. The flexible couplings come in many types such as bellows, spring, Oldham, jaw and Schmidt type. All these flexible couplings are relatively bulky and heavy, and are expensive and should be used in large mechanisms in which heavy components need to be adjusted frequently.

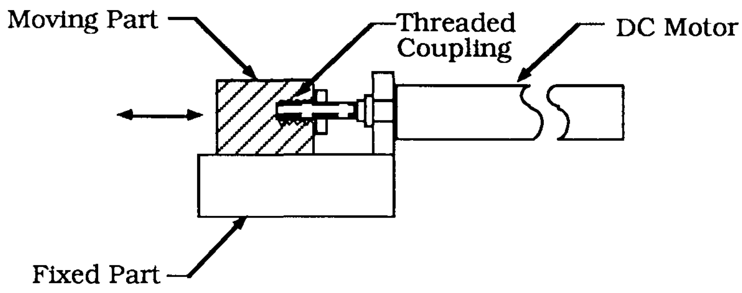

Figure 10. A linear mechanism with a threaded coupling between the actuator and the moving component

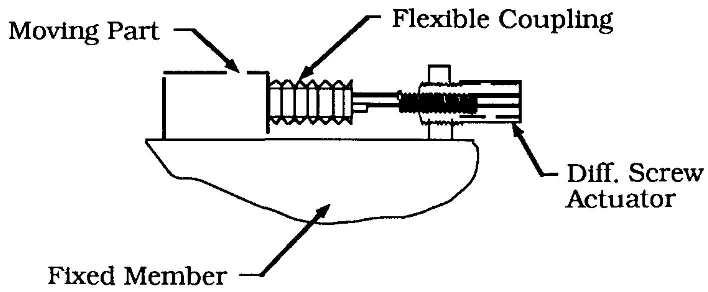

Figure 11. A flexible coupling interface for linear mechanisms

For large travels and heavy loads, the actuator may be coupled to the moving part through a lead screw shown in figure 12. The actuator is coupled to the main screw while the moving component is attached to the nut. The backlash and wobble of the nut can be minimized by preloading the nut. The friction can be reduced by using ball or roller bearings between the screw and nut. The lead screws are large in size and expensive but can produce very linear travel over a long range.

3.4 *The preloading methods*

Most of the mechanisms employ some form of preloading arrangement to ensure a positive movement, free of backlash, when the adjustment is made. The selection of a suitable type of preloading method depends on such design factors as the range and frequency of adjustment, load capacity, cost and size of the adjustment mechanism. In adjustments with a long travel range, a compression or an extension spring must be used for preloading the moving part against the stationary part. Typical spring preloading methods are shown in figure 9 and 13, although there can be many variations of these methods. Normally the springs can be placed around the adjustment screw or can be centered between two adjacent adjustment screws to preload both screws with one spring.

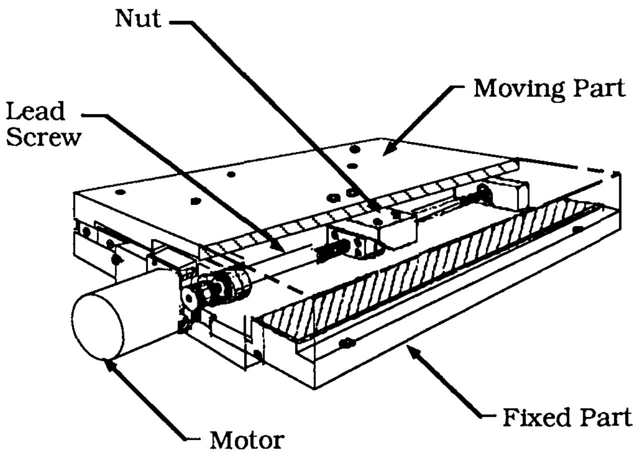

Figure 12. A translation stage with a lead screw coupling

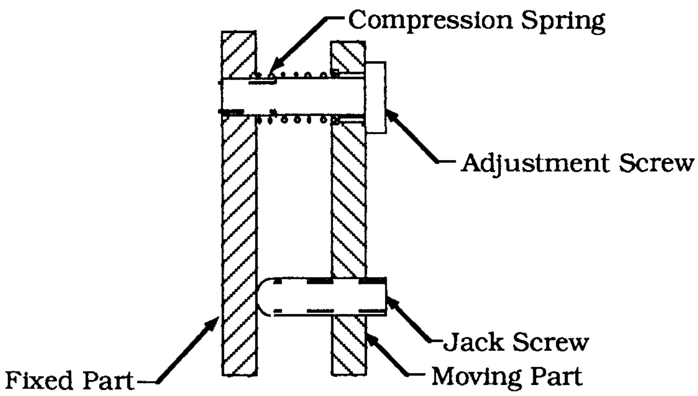

Figure 13. A mechanism with a compression spring for preloading and a jack screw for locking

Belleville and curved washers are used in compression mode to obtain high preloads over very small travels. These washers have very high stiffness and therefore, produce high loads as a result of relatively small compressions. These washers are compact in size and are very economical and suitable for high shock applications. The travel range of mechanisms using Belleville washers can be increased by stacking the washers as shown in figure 14.

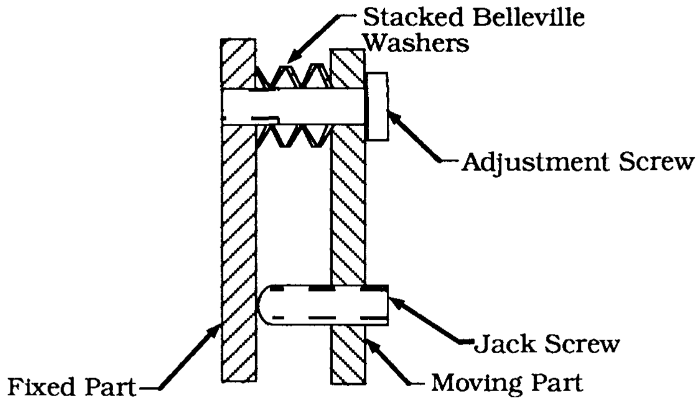

Figure 14. A mechanism with stacked Belleville washers for preloading and a jack screw for locking

3.5 *The locking methods*

After an element has been adjusted, it must be locked in place to retain the adjusted position. The design factors affecting the choice of a locking method are the frequency of adjustment, shock, vibration, weight, size and cost requirements. The locking can be accomplished by locking the actuator itself to prevent its accidental movement, tampering or its drift under environmental vibrations. For micrometers or screw type actuators, simple caps or covers can be used to prevent accidental movements. The movement due to vibrations can be prevented by using set screws to lock the rotation of the actuator screws. The second option is to positively lock the moving element relative to the fixed structure, and several methods are available for doing this. If the optical element is going to be adjusted and aligned only at assembly, it can be locked in place by using epoxy bonding shown in figure 9. The epoxy locking has the advantage of being a very low cost method but the main disadvantage is that the mechanism can not be readjusted without disassembly, which is generally very difficult and poses a great risk of damaging the parts.

Jack screws or locknuts, shown in figure 14 and 15, are economical ways of locking the mechanisms that do not require a great precision. The reason for lower accuracy is that a large force can be exerted on the adjusted element when a locknut or jack screw is tightened. The advantages of these methods are that these are compact in size and can be disassembled very easily without posing any risk of damage to the mechanism parts.

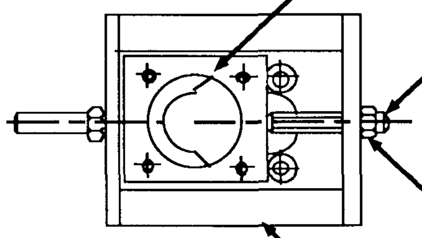

Figure 15. A linear stage with locknuts to retain the adjusted position

The vee and collar clamps are not commonly used because these are bulky and expensive to machine. Moreover, the bearing surface on the moving element must be parallel to the fixed structure to achieve effective locking. For motorized actuators, a closed loop feedback control system can be employed to retain the adjusted position of the moving element. As mentioned earlier, this method is expensive and is used only in those mechanisms which require real time adjustment.

4. SELECTION CRITERIA FOR COMPONENTS OF ROTARY ADJUSTMENT MECHANISMS

A number of choices are available for the components of a rotary mechanism depending on the performance requirements such as frequency, range and resolution of angular travel, shock, load capacity, cost and size of the mechanism. A number of components that are used in linear mechanisms can also be used for rotary mechanisms either in the same configuration or in their rotary version. These choices along with some design guidelines are discussed below.

4.1 *The interfaces*

The choice of a suitable interface between the rotating part and the fixed structure depends on such design criteria as the range and frequency of adjustment, shock, load capacity, cost and size requirements. As in the case of linear mechanisms, rotary versions of the bearings discussed in section 3.1, are more commonly used to interface the rotating part to the fixed part. Spherical and journal bearings, shown in figures 16 and 17 are used for light duty cycles because of friction and wear problems. These bearings are compact in size and are inexpensive as compared to rotary ball, roller and air bearings, which are used for heavy loads that are adjusted frequently.

For small angular adjustments, a flexural pivot (Bendix type) offer the advantages of friction and backlash free angular adjustment. These commercially available pivots are small in size and have low hysteresis. The application of these pivots in a mirror mount has been described by Rundle[2] in detail.

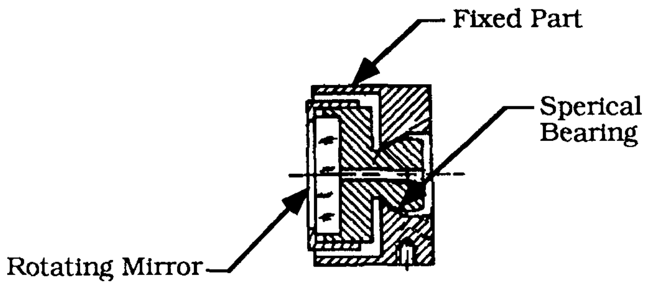

Figure 16. A mirror mount with a spherical bearing interface

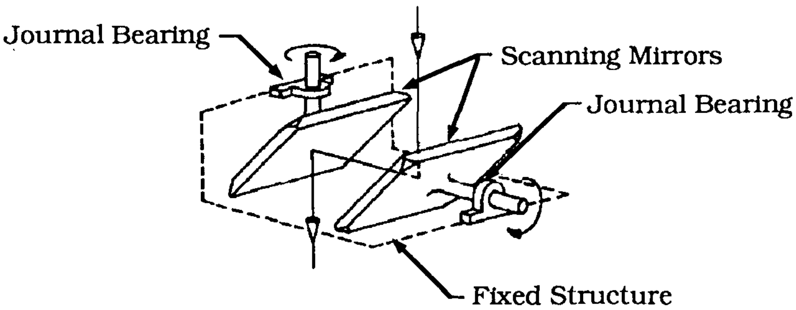

Figure 17. A rotary mechanism with journal bearings

4.2 *The actuators*

The actuators used in rotary mechanisms are very similar to those used in linear mechanisms discussed in section 3.2. Screws are used in low cost applications for small angular adjustments as shown in figure 18. Micrometers and differential micrometers are used when more precise adjustment with a readout is required. Commercially available rotary stages use both types af micrometers extensively. Once again the motorized actuators are used in applications requiring large and frequent angular travels or for real time adjustments..

4.3 The *coupling methods*

Some of the coupling methods for linear mechanisms discussed in section 3.3 can also be used in rotary mechanisms. The round tip of an actuator can bear against a flat, cone or a spherical socket. The advantages and disadvantages of these arrangements have already been discussed in section 3.3. These interfaces can only be used for very small angular adjustments since the tip of the actuator is sliding relative to the rotating part and loses a good contact with the rotating part for larger angles. A typical mechanism using a ball/flat type of coupling is shown in figure 18.

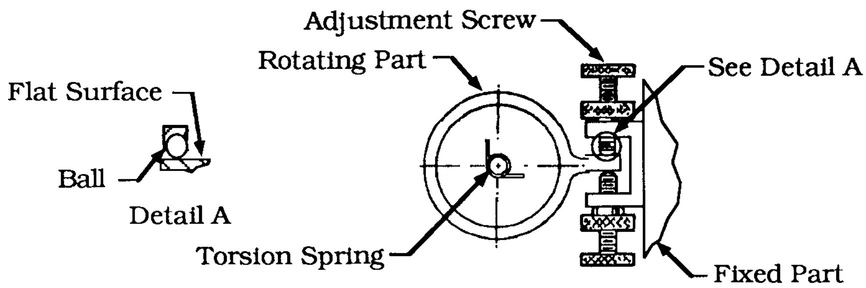

Figure 18. A rotary mechanism with screw actuators, a ball/flat interface and a torsion spring for preloading

For large and frequent angular adjustments, an actuator can be coupled to the rotating part through a flexible type of coupling or a universal type of joint as shown in figures 19 and 20. These types of couplings can tolerate relatively large misalignment between the axes of rotation of the actuator and the moving part. The principle disadvantages are large size, weight and cost.

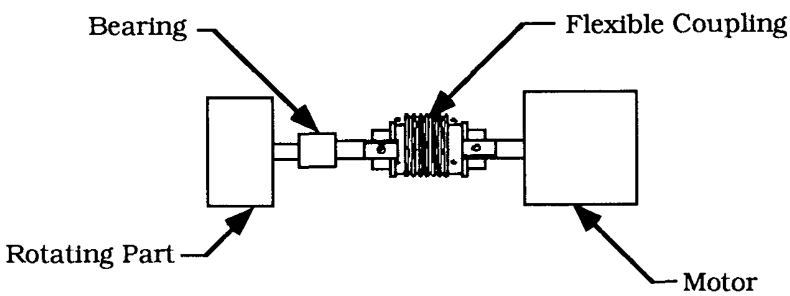

Figure 19. A flexible coupling is used to interface the motor with the rotating part

Sometimes, linear actuators are used in rotary mechanisms because of their lower cost and compact size. In such cases the linear motion of the actuator is converted to a rotary movement through a worm and gear or a rack and pinion arrangements shown in figures 21 and 22. In these mechanisms, the part to be adjusted is attached to the rotating gears. These mechanisms are expensive because of their complexity.

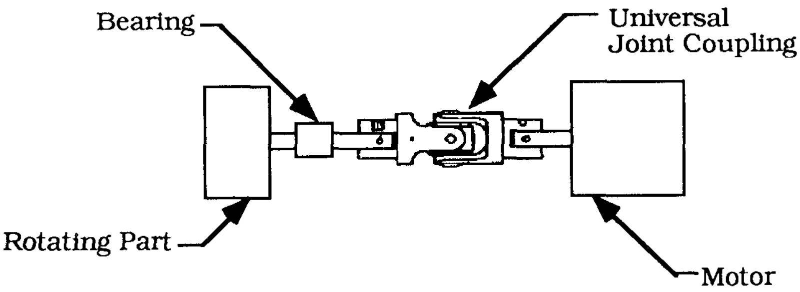

Figure 20. A universal joint coupling for rotary mechanisms

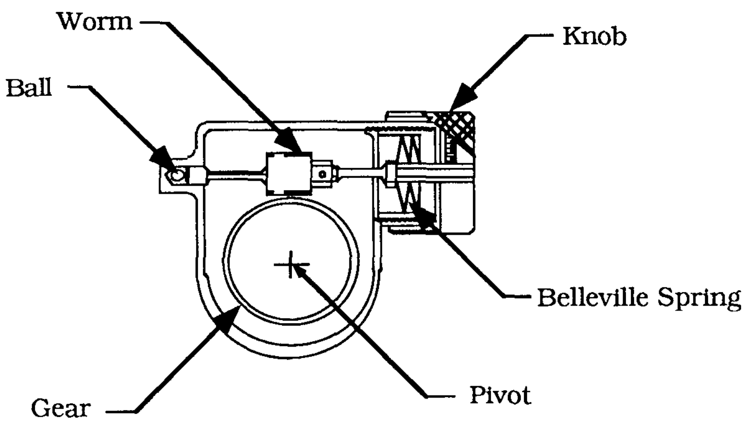

Figure 21. A rotary mechanism with a worm/gear interface and Belleville washers for preloading

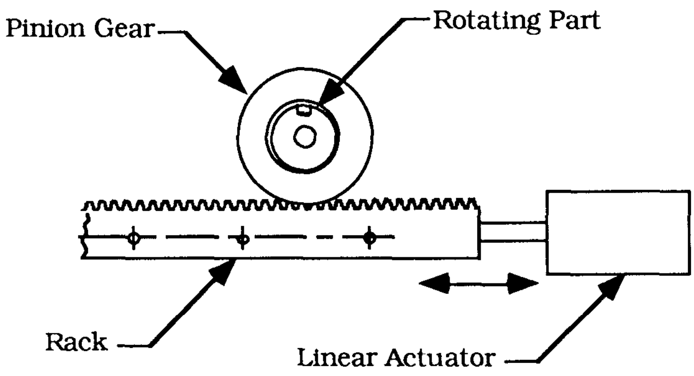

Figure 22. A rack and pinion interface for rotary mechanisms

4.4 *The preloading methods*

The selection of a proper preloading method to obtain a backlash free rotary adjustment is based on the same design factors that are discussed in section 3.4 for the linear mechanisms. The tension or compression springs, shown in figure 23, are extensively used for preloading purposes because of their low cost, and also because these can be used over a fairly large angular range. The application of Belleville washers for preloading is shown in figure 21. As mentioned earlier, these washers are used for high preloads over small adjustment ranges. For larger angular rotations, a torsion spring , shown in figure 18, can be used for preloading the rotating part. One end of the spring is attached to the rotating part, while the other end is attached to the fixed structure.

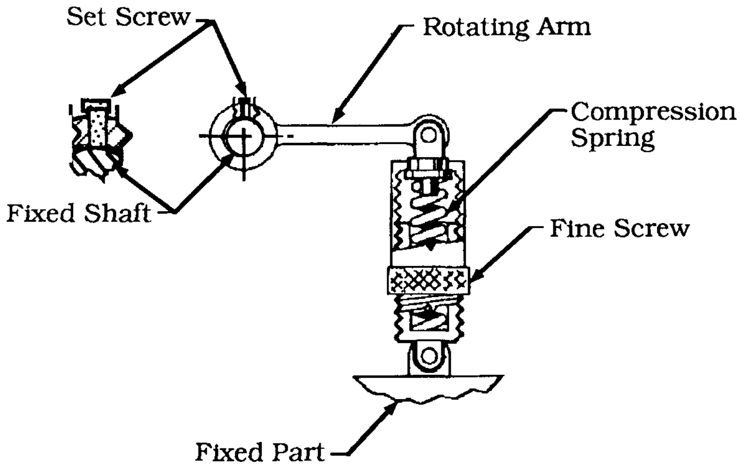

Figure 23. A rotary mechanism with a compression spring for preloading and a set screw for locking

4.5 *The locking methods*

The design factors affecting the choice of a suitable locking method are similar to those for the linear mechanisms as already discussed in section 3.5.

These include set screws, clamps, epoxy, and locknut. The mechanism shown in figure 23 employs a set screw to lock the rotating arm against the fixed shaft after the required adjustment has been made.The mechanism shown in figure 24 uses a collar clamp for locking purposes. The clamp is rigidly attached to the rotating part. After the adjustment has been made, the screw in clamp is tightened to achieve the clamping action to lock it against the shaft which is part of the fixed structure. In the same fashion, a locknut or epoxy bonding may be used for locking purposes. The relative advantages and disadvantages of all these locking methods have already been discussed in section 3.5.

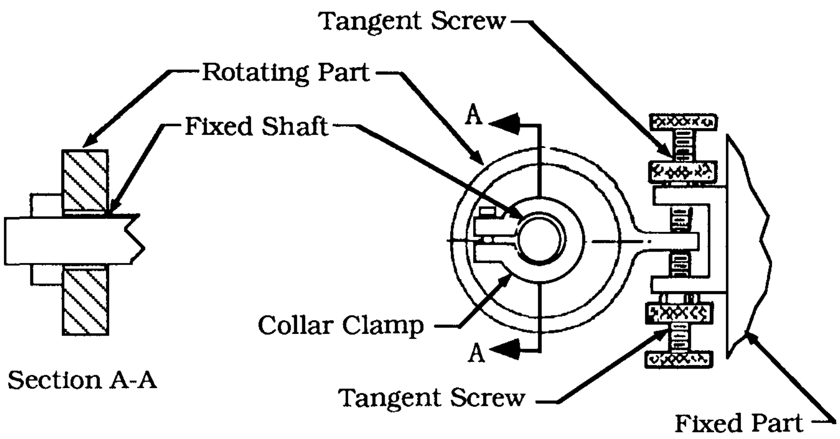

Figure 24. A rotary mechanism with a collar clamp for locking

5. SELECTION CRITERIA FOR COMPONENTS OF TILT ADJUSTMENT MECHANISMS

The design factors for selecting a suitable type of components for tilt mechanisms are the same as for linear and rotary mechanisms. If an adjustment mechanism is designed with three mutually orthogonal adjustment points, it can be used to perform linear as well as tilt adjustments. When the three actuators are moved equally, an axial movement results. However, if only one of the actuator is moved, a tilt adjustment about an axis defined by the two others is achieved. Therefore, a number of the same components that are used in linear mechanisms, can also be used in tilt mechanisms. The application of these parts in tilt mechanisms is discussed briefly below.

5.1 *The interfaces*

The tilting component can be attached to the fixed structure through rotary bearings (journal, ball, roller, air), flexures (Bendix, flat blade) or a traditional kinematic interface. The examples of mechanisms using two of these interfaces are shown in figures 25 and 26. The tradeoffs for these type of interfaces have already been discussed under linear and rotary mechanisms.

5.2 *The actuators*

The actuators used in linear and rotary mechanism can also be used in tilt mechanisms. The screws and micrometer adjustments are used in manual mechanisms, and are extensively employed in commercial tilt stages and mirror mounts. One such stage using a micrometer is shown in figure 27. Once again, the motorized actuators are large in size and expensive, and are used when real time and frequent adjustments are required.

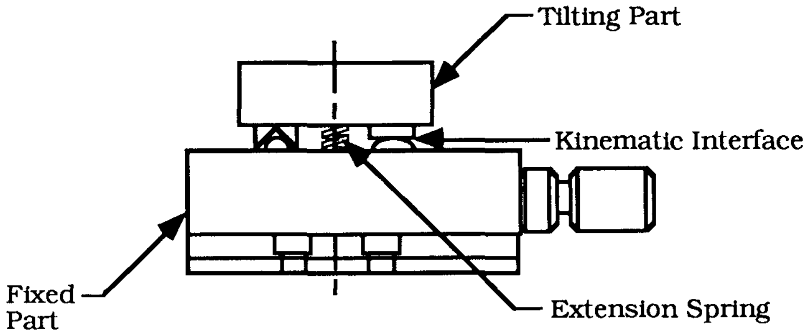

Figure 25. A tilt stage with a kinematic intaerface and an extension spring for preloading

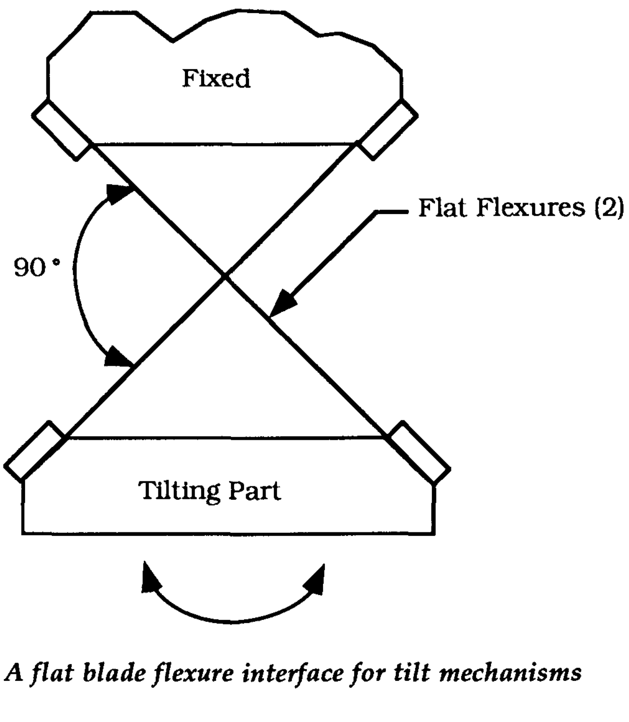

Figure 26. A flat blade flexure interface for tilt mechanisms

5.3 *The coupling methods*

As in linear and rotary mechanisms, the rounded tip of the actuator can bear against a flat surface, cone or a spherical socket in tilt mechanisms The ball/flat contact is illustrated in figure 27. The flat surface can be replaced by a cone or a spherical seat to increase the contact area and to minimize the contact stresses in those tilt mechanisms , which are adjusted frequently and require a higher load capacity.

5.4 *The preloading methods*

The preloading methods employed in linear mechanisms can also be used in tilt mechanisms. These include springs and washers as discussed in section 3.4. A commercial tilt stage showing an extension spring for preloading the tilt platform is shown in figure 25 The extension or compression springs can be centered between two adjacent actuators to achieve a uniform preloading. For smaller tilts and higher preloads, stacked Belleville or curved washers can be used in place of springs. The advantages and disadvantages of these preloading methods have already been discussed under linear adjustment mechanisms.

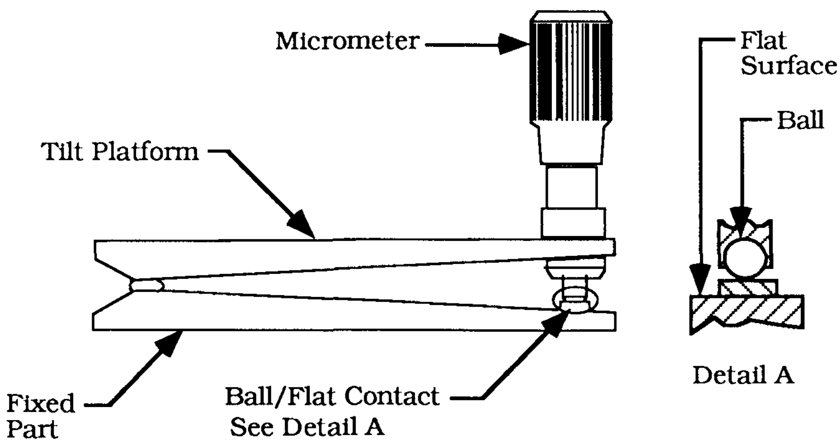

Figure 27. A tilt stage with a micrometer actuator and a ball/flat contact

5.5 *The locking methods*

The locking methods for tilt mechanisms are similar to those employed in the linear adjustment mechanisms. These include set screws, jack screws, locknuts, clamps and epoxy. The set screws and locknuts are used for temporary locking in coarse adjustment tilt mechanisms. The epoxy locking is economical and simple in design but is used those mechanisms which are adjusted at initial assembly and alignment only. As in the linear and rotary mechanisms, a closed loop control system can be used to retain the desired tilt adjustment in real time position control applications.

6. DESIGN GUIDELINES FOR USING ADJUSTMENT MECHANISMS IN OPTICAL SYSTEMS

An adjustable optical mount is inherently more complex, expensive and less stable than a comparable fixed type of mount. Therefore, a careful trade-off design study must be conducted to weigh the benefits of an adjustable optical mount against the potential stability and cost drawbacks. A good summary of how and when adjustment mechanisms must be incorporated in optical systems has been presented by Vukobratovich[3].

The decision to use adjustable optical mounts is dictated by the sensitivity analysis performed by the optical designer. This analysis defines the assembly tolerances for the optical system to achieve the image resolution and quality requirements. For systems with high image resolution requirements, usually the alignment tolerances of the optical elements exceed the practical fabrication tolerances for the optical elements and the associated mechanical hardware. This problem is further compounded by the stack up of machining tolerances and inspection uncertainties when the optical system has a large number of mirrors and lenses. In such applications, it is economical and time saving to manufacture the optical and mechanical parts to rather loose tolerances and provide adjustments for a few sensitive optical elements. These elements are then adjusted to compensate for the errors and uncertainties in the positions of other optical elements. Therefore, a rigorous optical sensitivity analysis must be performed to identify the optical elements that have the strongest effect on the image quality of the system.

Once the type of the adjustments required for an optical element have been determined, the next step is to design an adjustable mount to provide the required adjustment range and resolution. The glass optical elements are normally assembled in a metal frame, and an adjustment mechanism is provided between the frame and the fixed mounting structure. This way, a direct contact between the actuator and the glass element is avoided, and the element is shielded from the high contact stresses at the tip of the actuator. Providing an adjustment range, which is longer than that determined by the optical analysis, can be very risky. Such mounts can be assembled far off from their required nominal position, and a lot of time may be wasted during alignment to obtain any image at all. In such cases, it is better to design the mount such that it can be shimmed at assembly in case the range of adjustment is found to be inadequate. After the optical system has been aligned, the adjustable mounts must be positively locked to prevent misalignment due to accidental tweaking or drifts due to vibrations. The adjustments that are used at initial assembly only can be designed to have lockable mounts with removable actuators. This approach not only saves on the cost of actuators, but also eliminates the risk of accidental misadjustment later on.

The adjustable mounts should be designed to tilt or rotate about the principal points to avoid cross talk between axial and tilt adjustments. The cross coupling of adjustments can be very frustrating because several iterations of tilt and axial adjustments may be required to achieve the alignment. The adjustable mirror mounts must be designed to tilt the mirror about its vertex to avoid an unwanted image shift. The adjustment points in a tilt mechanism should be positioned in a mutually orthogonal pattern relative to the axis of the optical element. Such mounts are easy to adjust and produce predictable movements.

The adjustment mechanisms must be designed to have a large mechanical advantage such that a large axial movement or rotation of the actuator will incrementally move the optical element. This design feature can also save valuable alignment time because there is a less likelihood of accidentally overshooting the optimum position. If feasible, the mechanisms must be designed to have a coarse as well as a fine adjustment. The coarse alignment can be quickly achieved by using the coarse adjustment, while the fine part of the adjustment is only used to optimize the quality of the image.

A number of translation, rotary and tilt stages, mirror, lens and gimbal mounts are available commercially. These mounts are economical, precise and quite rugged, and are very suitable for prototypes and laboratory setups. Their main disadvantage is their bulky size and weight, which makes their use impractical in the systems with several optical elements that are packaged together tightly. If weight and size are not a problem in an application, it is far more economical and time saving to use commercial mounts rather than designing and fabricating the custom mounts.

While the adjustment mechanisms offer several advantages, the disadvantages of the adjustable mounts must not be overlooked, and provisions must be made in their design to minimize the negative effects on the optical system. First of all, the number of adjustable optical elements in a system must be kept to an absolute minimum. This not only save on the fabrication cost but also maximizes the long term stability of the system. The adjustable mounts are less rigid and more unstable than fixed mounts, and therefore, experience drift with time. The adjustments often induce non linear and unpredictable effects in optical systems. The adjustable mounts are mechanically weak and are more susceptible to drifts due to shock loads, vibrations and temperature variations.

7. CONCLUSIONS

The design choices for various components that make up the linear, rotary and tilt adjustment mechanisms have been presented. The advantages and disadvantages of these choices have been presented to help the designer in choosing the most suitable parts for a particular applications. The design guidelines for incorporating the adjustment mechanisms in optical systems have been presented. The adjustment mechanisms play an important role in the integration and alignment of sophisticated optical systems which have tight positioning tolerances. By incorporating these mechanisms in the optomechanical design of the systems, it becomes feasible and economical to produce and assemble such optical systems to very high alignment accuracies, which in turn greatly enhances the image quality produced by these systems. For this purpose, the application and designs of two adjustable mirror mounts for a submicron lithography system have been discussed by Ahmad[4].

8. REFERENCES

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