ISHELL TECHNICAL NOTE

PRELIMINARY ALIGNMENT PLAN: LASER ALIGNMENT I

Original Author: Tim Bond
Latest Revision: Tim Bond
Approved by: XX

NASA Infrared Telescope Facility
Institute for Astronomy
University of Hawaii

Revision History

Revision No.	Author & Date	Approval & Date	Description
Revision X	Tim Bond Dec 5/12	Tim Bond Dec 5/12	Preliminary Release.

Contents

1 Introduction / Document Purpose

The purpose of this document is to outline the procedures that will be undertaken in the initial alignment of the internal optics of the ISHELL instrument. In particular, the details of the use of a laser for the refinement of the optical element's angular registration are established.

2 Summary of Alignment Procedures

In summary, the following steps will need to be performed during the "Laser I Alignment" procedure:

- A laser is mounted to the periphery of the optical bench and adjusted to the level of accuracy required. In addition to a laser, several penta prisms and a set of CCD detectors are also mounted onto the periphery of the optical bench.
- The laser is aligned to the entrance and exit port of the optical bench using additional CCD detectors mounted into custom machined fixtures. These fixtures are examined with a metrology microscope after the CCDs are attached in order to determine their location on the fixture.
- The first optical element is assembled onto the optical bench to the tolerances specified by the initial alignment procedures using standard shop practices and utilizing a coordinate measuring machine.
- A blank is mounted into the second optical elements mounting fixture, and metrology is performed to ensure that the blank is located to the level required. A CCD is attached to the blank at a known position (relative to the seating points of the blank). And the laser is imaged onto the CCD.
- The tip and tilt of the first element are adjusted in order to center the laser to its desired location on the CCD at the second element.
- The procedure is then repeated sequentially along the optical path until all of the reflective elements have been assembled into their fixtures and adjusted in tip and tilt.
- The cold stop is then adjusted to be centered on the laser beam.

3 Details of Alignment Procedures

3.1 Mounting of Alignment Laser

An appropriate laser must be selected (power levels, beam size, wavelength, etc.) and then mounted repeatably to the optical bench. The mounting should be in such a way that the laser can be removed and reassembled onto the bench with minimal effort. Adjustment needs to be provided in order to align the laser, and the adjustment must be fine enough to meet the requirements stated below.

3.1.1 Selection of the laser:

A cost effective alignment laser needs to be selected with appropriate operating parameters.

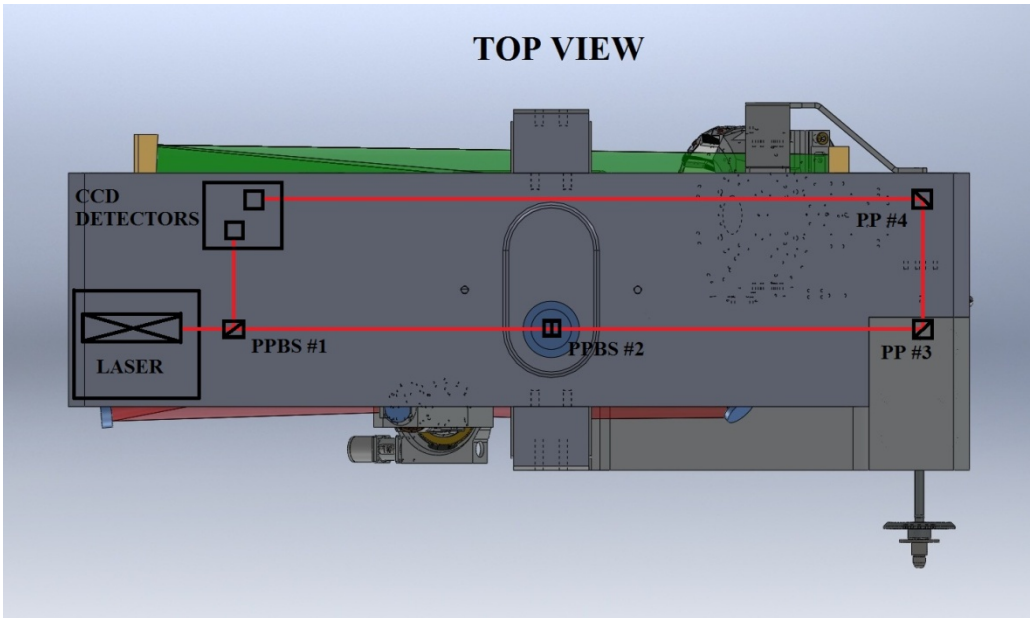
Some of the specifications that need to be considered are beam stability, power level, beam diameter, beam divergence, beam drift, operating wavelength, additional hardware requirements, etc.

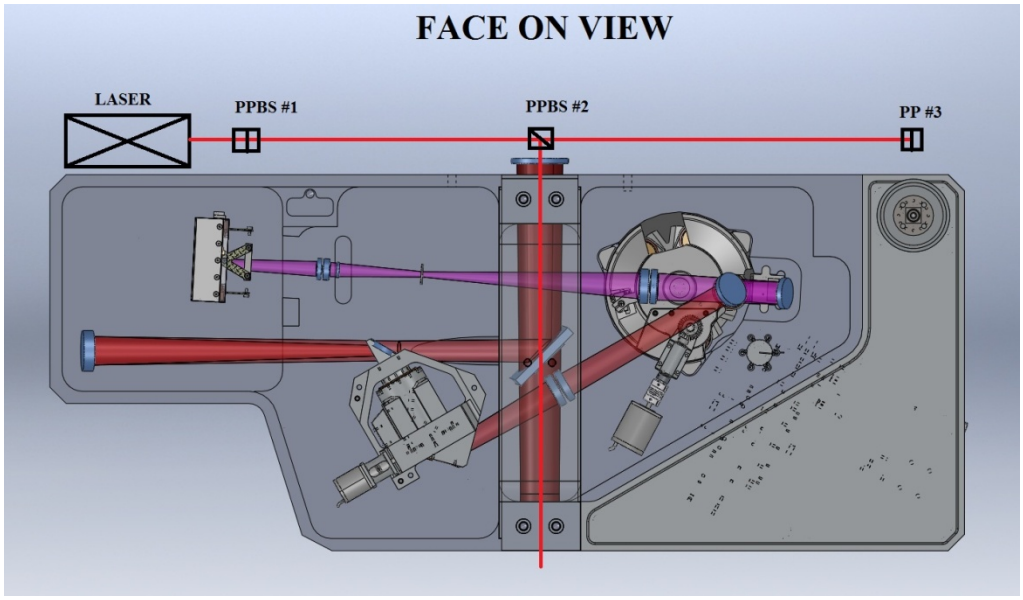
Details of the specifications for the laser are found in Appendix A.

3.1.2 Mounting of the laser:

The mounting of the laser itself onto the top of the optical bench needs to be done in such a way that it is somewhat repeatable. It may be the case that the laser will be mounted and removed several time during the course of the instrument assembly and alignment procedures and possibly again in the future if realignment is required.

Once the laser is located on the bench, there needs to be adjustments built into the mount that allow for refinement of both the angle and position (perpendicular to the beam) of the laser. Since the accuracy of the alignment can be improved by increasing the moment arms on each end of the laser beam (outside of the entrance port), it may be necessary to fold the beam in order to achieve the desired length. If the length needs to be increased past the length of the bench, simple penta prism folds may be incorporated.





A penta prism beam splitter needs to be located near the laser to create a second beam line for positional location of the laser. As close as possible to the penta prism beam splitter, a CCD camera will be mounted, and the location of the laser spot on the CCD can be used for the reference for one end of the laser beam line.

The laser will then pass through a penta prism beam splitter that is mounted immediately over the top of the entrance port of the instrument thus directing an additional beam line directly into the instrument. This penta prism needs to be mounted in a fairly robust mount that is protected from any possible bumping or misalignment for the duration of the alignment procedures. The mounting also needs to accommodate an initial alignment of the prism by allowing for translational adjustment along the “long axis” of the instrument (along pass through beam) as well as angular

adjustment about the axis of the pass through beam. This will allow for centering in both the entrance and exit ports of the optical bench.

Once the beam has been established, it can be confirmed at the entrance and exit ports of the bench to within a desired tolerance.

Two additional penta prisms (non-beam splitter type) will be required on the opposite end of the optical bench as the laser, and these will also need to be robustly mounted with protective covers. It may be possible to mount these prisms without adjustment as their sole purpose is to deliver the laser beam to a CCD detector at the far end of the bench. They do need to remain accurately aligned throughout the alignment procedures.

The specifications that need to be determined for the actual mounting of the laser are:

- The total amount of adjustment required in decentration.
- The resolution of adjustment required in decentration.

- The amount of adjustment required in tip/tilt.
- The resolution of adjustment required in tip/tilt.

In addition to the above, the following specifications need to be established:

- The location and accuracy of the fiducials used for initial laser alignment (i.e. the entrance and exit port on the optical bench).
- The mounting locations of the various penta prisms and penta prism beam splitters as well as a tolerance on the location.
- The total adjustment required for the various penta prism and penta prism beam splitters as well as a resolution on the adjustment.

The following chart is a first estimate of the adjustments required for the various elements within the laser alignment path:

ELEMENT	ADJUSTMENT	TOTAL REQUIRED	RESOLUTION REQUIRED	COMMENTS
LASER	DX, DY RX, RY	250 µm 0.15° (~10 arcmin)	25 µm 0.0025° (~10 arcsec)	Req. fine adjustment Req. fine adjustment
PPBS #1 (laser)	TZ RZ	250 µm 1.0° (60 arcmin)	50 µm 0.15° (~10 arcmin)	One time shim One time shim
PPBS #2 (entrance)	TZ RZ	250 µm 0.15° (~10 arcmin)	25 µm 0.0025° (~10 arcsec)	Req. fine adjustment Req. fine adjustment
PP #3 (90° fold)	RZ	1.0° (60 arcmin)	0.15° (~10 arcmin)	One time shim
PP#4 (90° fold)	RZ	1.0° (60 arcmin)	0.15° (~10 arcmin)	One time shim
CCD (near end)	DX, DY	250 µm	50 µm	One time shim
CCD (far end)	DX, DY	250 µm	50 µm	One time shim

The initial laser alignment should take place with the optical bench mounted on some form of support fixture and held in its “zenith” orientation. The support fixture needs to mimic the mounting and support scheme that will be used for locating the optical bench inside the vacuum jacket. This will ensure that the optics are being consistently aligned in the most probably orientation the instrument will experience – namely zenith oriented.

Ideally the handling fixture will allow for the tilting of the entire bench such that assembly can occur with the bech facing upwards. Note that this requires three different orientations – one with the optical entrance port facing zenith, one with the foreoptics side of the bench facing zenith, and one with the spectrograph side of the bench facing zenith.

Initially a scheme was considered in which the beam passed directly through the optical bench (entrance port to exit port) and this would have been ideal except for the fact that once the alignment of the first element (the dichroic) was performed, the output beam would no longer be available for maintaining the alignment of the laser.

With the laser mounted directly to the optical bench, it is now possible to begin assembly of the optics onto the bench.

3.2 First Element Tip/Tilt Adjustment Procedure:

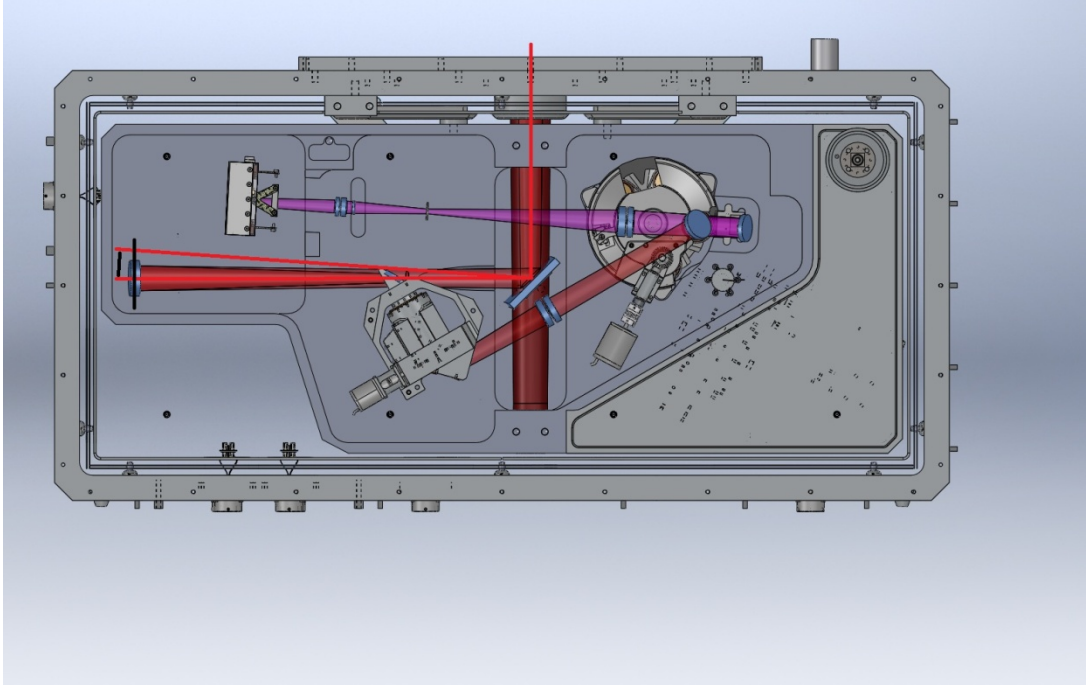
The procedure for the mounting and tip/tilt adjustment of the first element in the path (the dichroic) would be as follows:

The next element in the optical path needs to be determined (in this case, the collimator mirror in the next element in the sequence). A special fixture needs to be made that will allow mounting of a CCD array at the next elements mounting fixture, and centered as accurately as possible. (Basically, the CCD array must be positioned in such a way that the lasers beam would fall entirely within the CCD's field, if the laser were pointed directly to the center of the mount).

There will be some tolerance stack up here that will be result from both the fabrication tolerances of the mount, the reaffirmation of the locations with the coordinate measuring machine, and with the metrology used to determine the location of the CCD pixels on the blank fixture. This stack up is accounted for within the scheme.

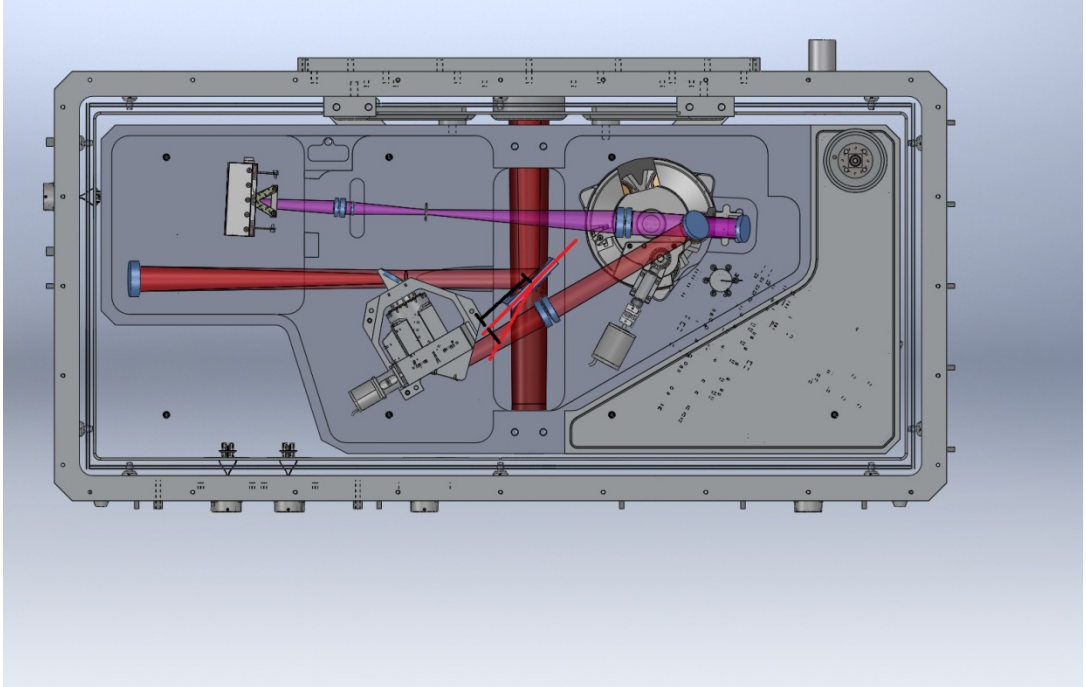
The laser is then used to illuminate the CCD and adjustments can be made to the dichroic (tip and tilt only) accordingly.

A calculation can be performed to show how accurately one can adjust the dichroic based on the length of the lever arm to the next element (the collimator) and precision with which one can expect to centroid the laser at the next element.



It is also possible to determine how much adjustment is required at the dichroic element if some assumptions are made on the mounting scheme for the element. It will be necessary to mount the element within a cell, and that cell needs to be mounted onto the optical bench. The general process anticipated is that the mounts to the bench will be designed in such a way that a "one time" shimming process would be undertaken in order to refine the elements alignment. Once the procedure is performed, the element should not need to be adjusted again, and if in the future, removal of the element is anticipated, the mounting scheme needs to account for this.

Again a calculation can be performed in order to determine the requirements for the mounting scheme (resolution on the angular adjustment).



The mounts for the dichroic element must be designed in such a way to account for the adjustment required for alignment. Specifically, they must be designed to allow for adjustment resolutions that are practical for the alignment levels specified. This means that the actual placement of the shims may need to be further from the element than nominally designated.

The mounting scheme must also account for the fact that the shim will probably need to be removed for refinement, and will need to be replaced repeatably.

3.3 Sequential Element Tip/Tilt Adjustment Procedure:

Once an alignment laser is in place to provide a repeatable nominal optical axis, it is simply a matter of sequentially stepping through the optical elements in order to tighten down the required angles. This process can be applied to all of the reflective elements along the optical path, through to the detector.

Initially, a reflective element would be used in the slit wheel in order to continue on through the slit viewing portion of the instrument. Once the Slit viewer is fully aligned, it is simply a case of switching the reflective element at the slit, out for an actual slit (or transmissive element) and then alignment can continue on through the spectrograph portion of the instrument.

The accuracy in which the elements can be corrected has been determined and tabulated in the following chart. Also an indicator what the alignment requirement is has been shown, and how well the requirement is met is shown.

ELEMENT GEOMETRY				CENTROIDING ON ALIGNMENT ARRAY			
Considered Optical Element	Distance to Next Element	Next Optical Element	Alignment Tolerance (deg)	Required Ability to Centroid (mm)	Assumed Ability to Centroid (mm)	Corresponding Angle (deg)	% of REQ
Dichroic / Flat	556.000	Collimator	0.0120	0.116448369	0.025	0.002576249	21.47
Collimator	354.000	Fold F1	0.0120	0.074141588	0.025	0.004046312	33.72
Fold F1	148.852	Fold F2	0.0310	0.08053669	0.025	0.009622944	31.04
Fold F2	405.418	Fold F3	0.0310	0.219352269	0.025	0.00353313	11.40
Fold F3	125.700	SLIT	0.0240	0.052653096	0.025	0.011395342	47.48
SLIT	92.279	Fold F4	0.0240	0.038653739	0.025	0.015522431	64.68
Fold F4	692.071	Detector	0.0240	0.28989404	0.025	0.002069722	8.62
Detector	??	??					

It is also possible to show all of the required resolutions for the element mounts based on a nominal shim size and spacing. The following table demonstrates some of the possible combinations in order to meet the requirements. It is also possible to adjust some of the numbers in order to achieve a more simplified design, as long as the combination (shim distance and shim resolution) are able to achieve the necessary adjustment angle.

The following chart is a tabulation of the shim requirements for the element mounts through to the end of the slit viewer subsystem of the instrument.

ELEMENT GEOMETRY				ABILITY TO ADJUST			
Considered Optical Element	Distance to Next Element	Next Optical Element	Alignment Tolerance (deg)	Shim Resolution (mm)	Shim Distance (mm)	Adjustment Angle (deg)	% of REQ
Dichroic / Flat	556.000	Collimator	0.0120	0.0125	70	0.01023139	85.26
Collimator	354.000	Fold F1	0.0120	0.0125	70	0.01023139	85.26
Fold F1	148.852	Fold F2	0.0310	0.0125	70	0.01023139	33.00
Fold F2	405.418	Fold F3	0.0310	0.0125	70	0.01023139	33.00
Fold F3	125.700	SLIT	0.0240	0.0125	70	0.01023139	42.63
SLIT	92.279	Fold F4	0.0240	0.0125	70	0.01023139	42.63
Fold F4	692.071	Detector	0.0240	0.0125	70	0.01023139	42.63
Detector	??	??					

3.4 Alignment of the COLD STOP:

Once an alignment laser is in place and the reflective elements have all been adjusted to within their required tolerances, one can then establish proper alignment of the cold stop. Since the optical axis has been established for the laser, it is necessary to move the cold stop into alignment with this axis as close as possible (any misalignment at this point will propagate though the entire optical path, as all of the elements are being aligned to the laser)

It is assumed that a onetime adjustment will be required, and once this adjustment is performed, no further adjustments would be allowed (i.e. any further adjustments would cause a misalignment from the optical elements).

The exact process for this alignment needs to be further refined

3.5 Confirmation of Fiducial Locations in optical path:

An additional (optional) step that can be taken is to confirm the location of the mounting fiducials for the image rotator and the lens barrels once the alignment laser path has been established. The fiducials have been established using the coordinate measuring machine, but refinement and/or reaffirmation is also possible.

To do this the CCD would again need to be mounted onto an appropriate mounting blank and the blank moved to the various fixtures. The list of features that can be checked include:

- The telescope focus
- The cold stop
- The first and second bearing mount of the image rotator
- The fiducials for the mounting of the lens barrels
- The nominal positioning of the filter wheel
- The positioning of any baffling structures along the optical path

4 Additional General Comments

The optical bench will need to be fabricated in such a way as to allow for the mounting of the laser, penta prisms and CCD detectors onto the periphery of the optical bench. The mounting should be robust enough to ensure that alignment will be maintained throughout the entire procedure and the fixtures need to be easily removed and replaced should this be necessary during the commissioning phase of the instrument.

During the alignment of the elements onto the optical bench, the bench needs to be supported in a way that is similar to the way that the bench will be supported within the vacuum jacket. In particular, the bench should be supported by a three point contact scheme, using the same contact points anticipated for final mounting. The bench should also be held in an orientation equivalent to the orientation of pointing at zenith on the telescope.

Confirmation should be made that all safety procedures required are adhered to with use of the specified laser. Anyone tasked with working around the laser should be aware of the safety issues involved. Also anyone that is within a line of site distance of the laser during operation must be outfitted with the appropriate safety equipment (i.e. safety glasses)

There are several large beam members that are attached to the sides of the optical bench. These beam members need to be properly located and installed during all of the alignment procedures. Also any elements that are deemed to have a potential impact on the alignment of the optical bench needs to be installed or an appropriate dummy mass installed in its place.

5 Appendices

5.1 Appendix A: General Laser System Top Level Requirements:

The following are a list of the general top level requirements of the laser alignment system:

- The system needs to be stable over long periods of time, and over the temperature excursions that are expected within the laboratory environment.
- The system needs to be easily removable and reinstalled as may be necessary during the commissioning phase.
- The system needs to define the optical axis to a level of better than 25 µm locational and 0.0025° (~10 arcsec) angular through the entire length of the beam.
- The laser beam needs to be located to a positional tolerance of 25 µm at both the entrance port and the exit port of the optical bench
- The system needs to operate at any orientation with respect to gravity.
-

5.2 Appendix A: Laser Selection Requirements:

The following are a list of the requirements for the actual laser selected:

- The laser needs to
-

5.3 Appendix B: CCD Selection Requirements

The following are a list of the requirements for the actual CCD selected:

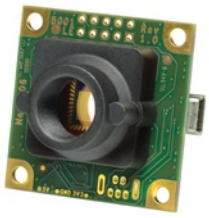
- The CCD needs to
-

The following excerpt from the Edmund Optics Catalogue shows a fairly inexpensive yet viable candidate for the CCD camera:

products : imaging : cameras : board level cameras

NEED HELP?
Our team is ready to assist you!

EO USB 2.0 Board Level Cameras



View More Images

- High Resolution
- Standard M12 x 0.5 Lens Mount
- Software SDK Included
- Adjustable Frame Rate via Binning, Sub-sampling or AOI

These board level cameras utilize popular USB 2.0 technology and are well equipped for use in laboratory or OEM applications. Interchanging lenses from our large selection of micro video products offers tremendous versatility for solving a host of machine vision and inspection applications. Each camera also includes software that allows the user to set a specified Area of interest (AOI), adjust gain, exposure time, frame rate, trigger delay and digital output (flash) delay and duration. The exposure, gain, and white balance can be set to a specified level or the camera can adjust these parameters automatically. The software allows capturing of still images in JPEG and Bitmap file format or video in AVI format. In addition, the software can perform edge enhancement, image mirroring and image binning, in the vertical and horizontal directions, as well as hot pixel correction. Direct Show (WDM), ActiveX and TWAIN drivers, as well as SDK documentation, are included.

Standard, Lite Edition and Harsh Environment versions also available.

Required USB 2.0 Cable (mini-B to standard-A) (#59-382) not included with camera.

Download Driver and Manuals.

Products | **Technical Images** | **Documents/Downloads**

View Legend

Description	Stock No.	Price	In Stock	Qty	
EO-0413BL 1/3" CMOS Monochrome USB2.0 Board Level Camera	NT62-281	$545.00	✔		BUY
EO-0413BL 1/3" CMOS Color USB2.0 Color Board Level Camera	NT62-282	$545.00	✔		BUY
EO-1312BL 1/2" CMOS Monochrome USB2.0 Board Level Camera	NT62-283	$735.00	✔		BUY

Model Number	EO-1312BL
Type of Sensor	MT9M001
Camera Sensor Format	1/2"
Sensing Area, H x V (mm)	6.6 x 5.3
Pixels (H x V)	1280 x 1024
Pixel Size, H x V (µm)	5.2 x 5.2
Pixel Depth	8-bit
Frame Rate (fps)	25
Type of Shutter	Rolling
Video Output	USB2.0
Mount	M12 x 0.5mm
Synchronization	Internal or Via Software
Dimensions (mm)	36 x 36 x 20
Weight (g)	12
RoHS	Compliant
CE Certified	Yes

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5.4 Appendix C: Misc. Additional Specifications:

5.4.1 Penta Prism Beam Splitters

The following excerpt from the Edmund Optics Catalogue shows a fairly inexpensive yet viable candidate for the penta prism beam splitters:

products : optics : beamsplitters : cube beamsplitters

NEED HELP?
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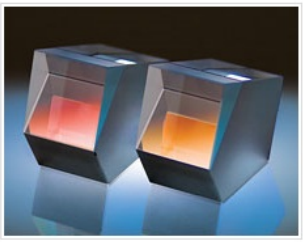
Penta Prism Beamsplitters



- 50% Reflection / 50% Transmission
- Beam Deviation Insensitive to Alignment
- Designed for Visible Wavelengths

Penta Prism Beamsplitters are constructed by cementing a precision penta prism and a wedge prism together, and applying an appropriate interference coating to one of the traditionally reflective surfaces. Since slight movements of a penta prism do not affect the true right angle at which light rays are reflected, the deviation between the transmitted and reflected light rays is highly controllable and will not vary by more than 10arcseconds.
Note: Outgoing beams are partially polarized.

Products | **Specifications** | **Documents/Downloads**

View Legend

Description	Stock No.	Price	In Stock	Qty	
12.7mm Penta Prism Beamsplitter, MgF_2 Coated	NT66-632	$170.00	✔		BUY
20mm Penta Prism Beamsplitter, MgF_2 Coated	NT66-633	$195.00	✔		BUY

Dimensional Tolerance (mm)	±0.10
Clear Aperture (%)	>90
Surface Accuracy (λ)	1/4 @ 633nm
Surface Quality	40-20
Beam Deviation (degrees)	90, 180
Beam Deviation Tolerance (arcseconds)	±10
Substrate	N-BK7
Reflection (%)	50 @ 450-680nm
Transmission (%)	50 @ 450-680nm
Reflection/Transmission Tolerance (%)	±5
Coating	MgF_2 on Entrance and Exit Faces
RoHS	Compliant

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25mm Penta Prism Beamsplitter, MgF_2 Coated	NT66-634	$215.00	✔		BUY

Showing **1-3** of **3** Items | Sort by Spec

5.4.2 Penta Prisms

The following excerpt from the Edmund Optics Catalogue shows a fairly inexpensive yet viable candidate for the penta prisms:

products : optics : prisms : penta prisms

NEED HELP?
Our team is ready to assist you!

TECHSPEC® UV Fused Silica Penta Prisms

- Ray Deviation of 90°
- Right Handed Image
- Optical Tool for Defining a Right Angle
- Additional Penta Prism Options Available

Penta prisms are five-sided prisms featuring a ray deviation of 90° and a right handed image. The reflecting surfaces are aluminized for increased efficiency. Slight movement of the prism does not affect the true right angle at which light rays are reflected, making a penta prism the ideal optical tool for defining a right angle in an optical system. TECHSPEC® UV Fused Silica Penta Prisms are made from UV fused silica which features low thermal expansion and excellent transmission throughout the UV, visible, and NIR spectral ranges.

Products | Specifications | Technical Images | Documents/Downloads

View Legend

Description	Stock No.	Price	In Stock	Qty	
5mm Fused Silica Penta Prism Uncoated	NT49-016	$69.50	✔		BUY
5mm Fused Silica Penta Prism UV-AR Coated and Aluminized	NT49-020	$79.50	✔		BUY
10mm Fused Silica Penta Prism Uncoated	NT49-017	$69.50	✔		BUY
10mm Fused Silica Penta Prism UV-AR Coated and Aluminized	NT49-021	$79.50	✔		BUY
20mm Fused Silica Penta Prism Uncoated	NT49-018	$85.00	✔		BUY
20mm Fused Silica Penta Prism UV-AR Coated and Aluminized	NT49-022	$95.00	EMAIL		BUY

Dimensional Tolerance (mm)	±0.10
Surface Accuracy (λ)	1/10
Surface Quality	20-10
Angle Tolerance (arcminutes)	±1
Substrate	UV Grade Fused Silica
Bevel	0.3mm x 45°
Coating	Entrance/ Exit Faces: UV-AR Reflecting Surfaces: Aluminized, Inconel and Black Paint Overcoat
Typical Energy Density Limit	Entrance/Exit Faces: 3 J/cm2 @355nm, 10ns Reflecting Surfaces: 0.3 J/cm2 @532nm & 1064nm, 10ns
RoHS	Exempt

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25mm Fused Silica Penta Prism Uncoated	NT49-019	$105.00	✔		BUY
25mm Fused Silica Penta Prism UV-AR Coated and Aluminized	NT49-023	$115.00	✔		BUY

Showing **1-8** of **8** Items | Sort by Spec

5.4.3 Electronics / Computer Control