Cerro Tololo Inter-American Observatory

CHIRON
instrument description

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Contents

1 Overview

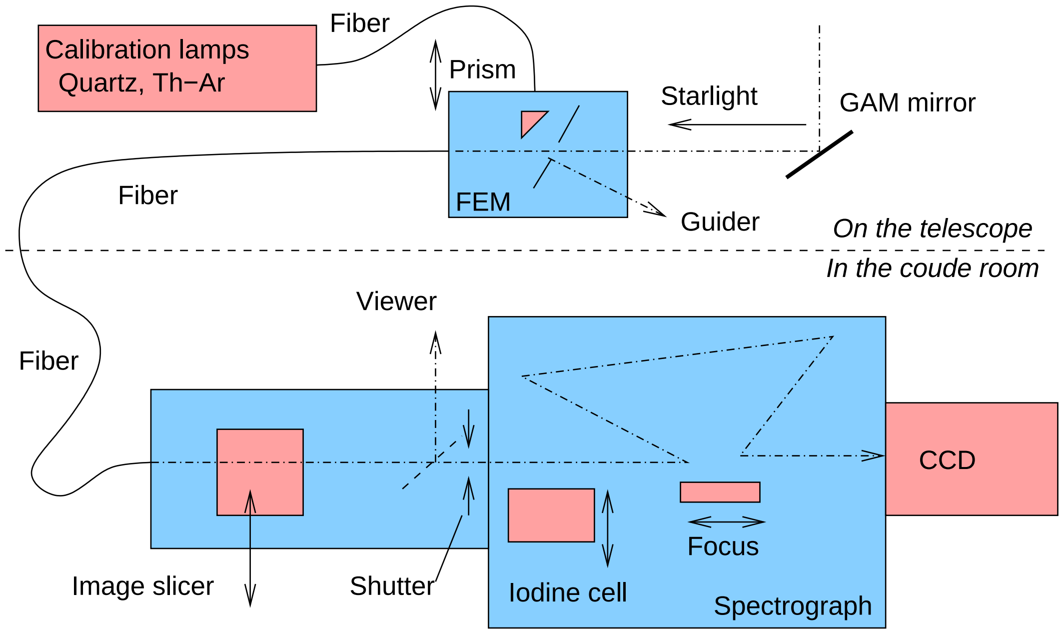

Figure 1: Light path in CHIRON, from the telescope to the CCD. Elements under user control are pink-colored.

CHIRON is a high-resolution fiber-fed echelle spectrometer installed at the CTIO 1.5-m telescope. It can record multi-order echelle spectra of single objects (stars) with spectral resolution up to $R = 80\,000$, 3 pixels per resolution element. The spectral format on the detector is fixed, covering the wavelength range from 4200Å to 8800Å without gaps [TBC].

Figure 1 shows main elements of CHIRON from the user perspective. We follow the path of starlight, directed towards the fiber module (FEM) by a diagonal mirror located in the telescope GAM (at certain position of the pickup arm). The star image is focused on a mirror with a hole; most of the light goes into the fiber, the remaining halo is reflected towards the acquisition/guiding camera. A small prism can be placed behind the mirror to feed calibration light (quartz or Th-Ar lamps) to the spectrometer.

The spectrometer is located on the coude room. The light beam emerging from the fiber can be re-shaped into a slit-like image by the *image slicer*, to increase spectral resolution without light loss. The slicer can be moved out of the way to work with bare fiber image (with spectral resolution decreased to $R \approx 30\,000$) or to mask the fiber by slits (increase resolution at the expense of light loss). A viewer with manually-activated mirror is used only for troubleshooting to see the sliced image. Other user-controlled elements are the shutter, iodine cell which can be placed in or out of the beam, and the focusing stage. The CCD is operated by a GUI-driven data-acquisition program.

CHIRON is designed to be very stable, its internal environment is maintained at constant temperature. Opening the spectrometer or any other intervention or manipulation are **strictly prohibited.**

2 Fiber feed

2.1 Telescope interface

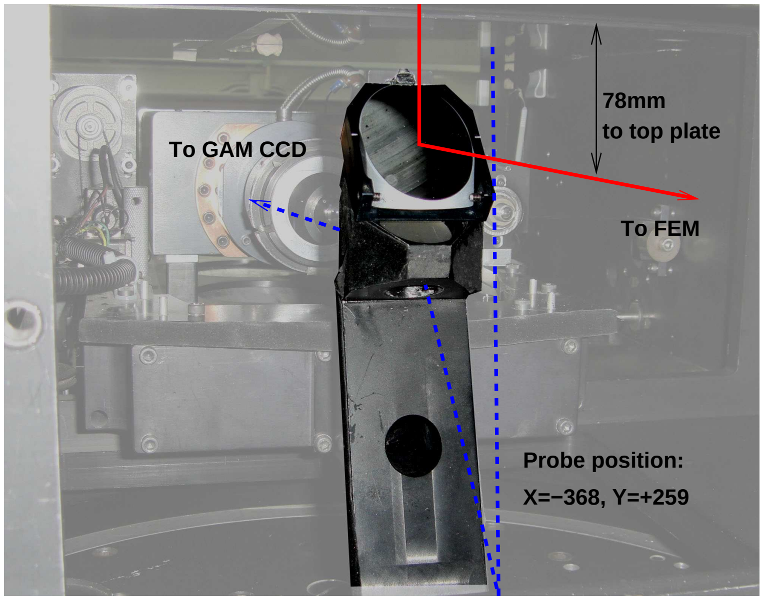

Figure 2: M1 mirror attached to the GAM probe.

The Guiding and Acquisition Module (GAM) of the 1.5-m telescope is normally used for offset guiding. It has been modified by adding a piggy-back mirror M1 on top of the guide probe (Fig. 2). Positioning this probe at the center of the field (X=−268, Y=+259) makes M1 to intercept the on-axis beam without vignetting and to direct it sideways, to the FEM which is attached to the GAM hatch door. The optical axis of the beam deflected by M1 is at 78 mm below the lower surface of the GAM top plate. Normal operation of the probe is not perturbed, it captures the field at a fixed offset and, if we are lucky to find guide stars there, the standard guiding is possible. The object would be centered in the GAM-camera field if we set Y=-96, but then FEM receives no light.

2.2 Front-End Module (FEM)

Figure 3 shows the FEM. When it is attached to the GAM, the space is restricted from all sides. To remove the FEM, loosen the 4 M4 screws, turn the FEM anti-clockwise and pull it away, leaving the screws in place. **Do not disconnect fibers and cables!** Be careful not to damage the cables and the optical fiber. Installation – in the reverse order. The FEM is permanently installed on the telescope, but any repair or trouble-shooting require its removal because the access is difficult.

The main components of FEM are shown in Fig. 4. The incoming beam is focused on the concave mirror M2 with two holes in it, one for the star and another, larger – for the sky (not used). The light which goes through the central hole is transformed from F/7.5 to F/5 by a pair of small lenses and is injected into the fiber with a core diameter 100 micron.

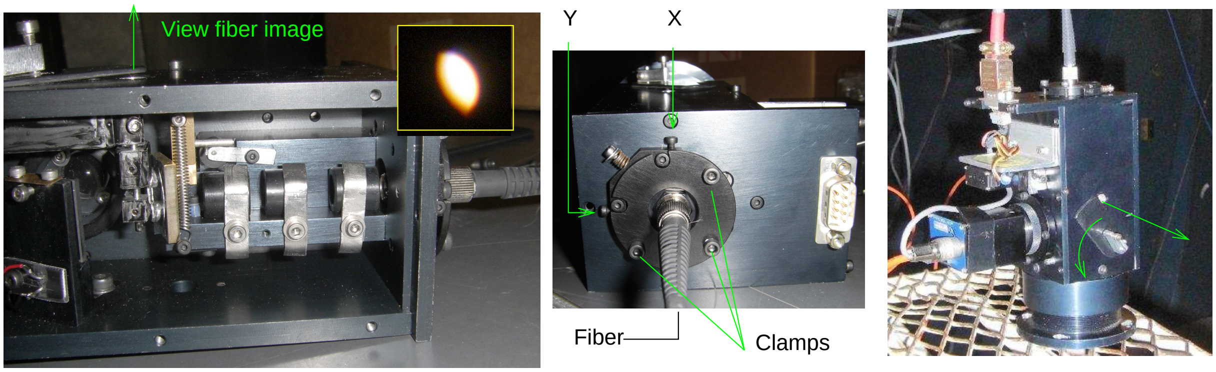

Figure 3: FEM. Left: box opened, alignment optics in place. The insert shows fiber image in mis-aligned condition. Center: fiber alignment screws. Right: FEM detached during alignment/service. The green arrows show where to look during fiber alignment.

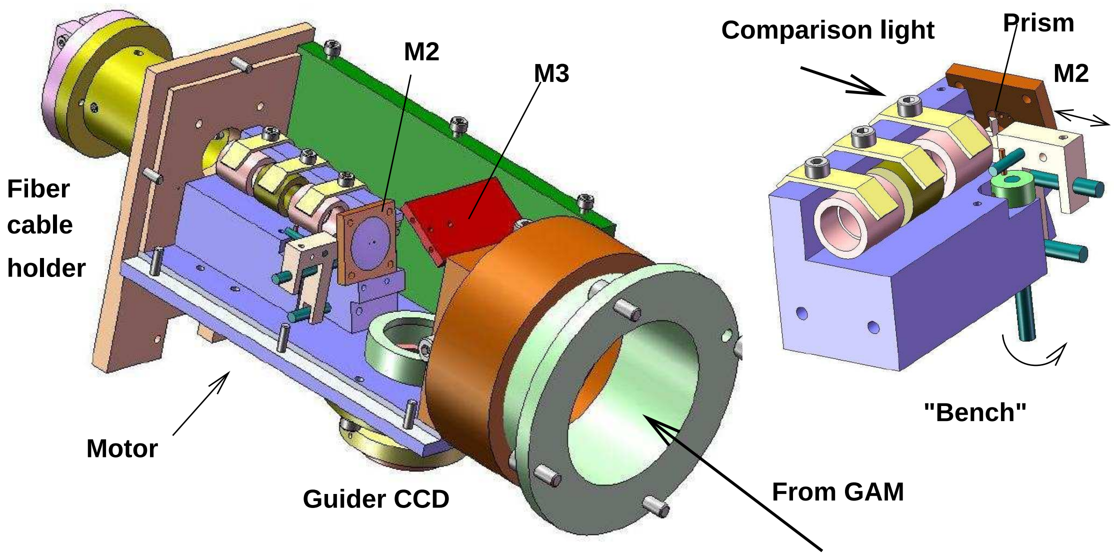

Figure 4: Schematic representation of the mechanical design of the front-end module. The fiber connector has been changed.

The co-alignment between the hole and the fiber is very important. To check it easily, an auxiliary optics (a small mirror and a strong eyepiece) can be lowered in front of M2 (green arrows in Fig. 3). The back-end of the fiber is illuminated (insert the viewer mirror in the FOB, replace eyepiece with a flashlight), the image of its front end can be seen through the hole in the FEM sidewall. Un-clamp the 3 M3 screws of the fiber connector, apply tiny corrections to the X,Y screws (M2). When the fiber is mis-aligned, the image is not round (see the insert). Center the fiber in the hole (get round image), then firmly clamp the fiber connector and re-check the alignment. Do not forget to retract the auxiliary optics after the alignment check!

The light which does not pass through the hole is reflected by M2, then directed by a flat mirror M3 to the optics of the guider. The 3x reduced image of the field (i.e. of M2) is formed on the CCD camera GC650 from Prosilica. The digital signal is sent via Ethernet cable to the guiding PC (see below).

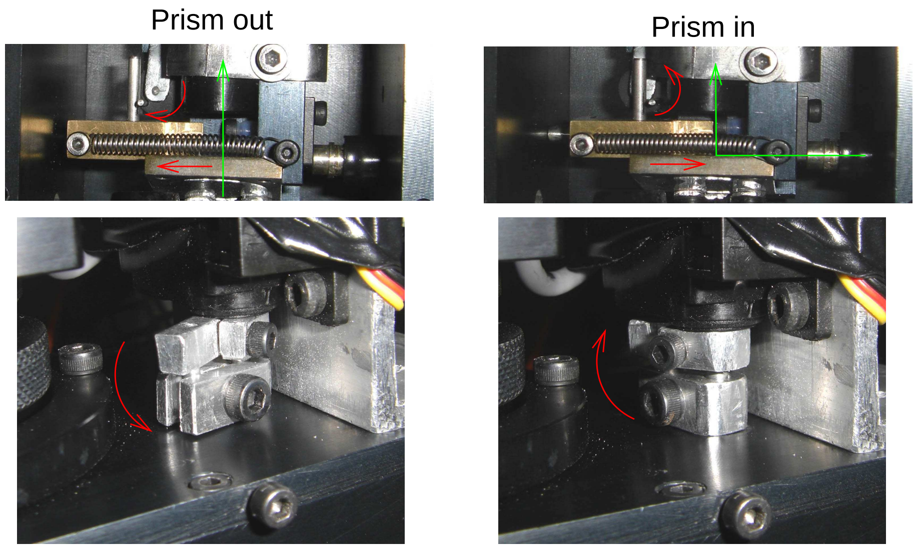

Figure 5: Operation of the comparison-light prism. The upper pictures show the prism holder, cam, and light path as can be seen in the opened FEM box. The lower pictures show corresponding motor positions on the lower FEM wall.

The light of the comparison lamps is directed into the main fiber by moving a small (2-mm) prism which slides behind M2. The prism is pushed by a cam mechanism with a finger which, in turn, is actuated by a small servo motor HS-85 from Hitek (Fig. 5).

2.3 Comparison lamps and electronics

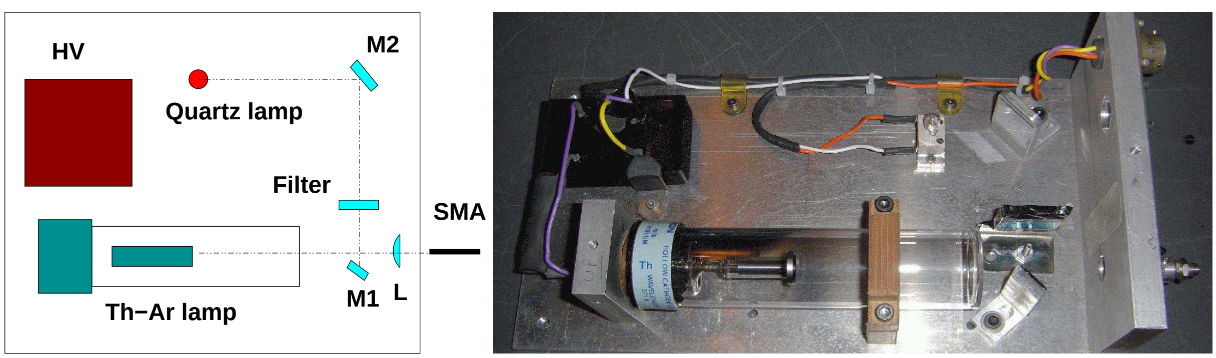

Figure 6: Optical scheme and picture of the Light Box.

The "light box" contains the thorium-argon spectral lamp and the quartz lamp. The SMA connector of the fiber (core diameter 0.4 mm) receives the image of the thorium cathode formed by a $F = 18$ mm lens (it is aligned with the fiber). The lamp is powered by 500 V voltage produced by the DC/DC converter in the light box, while a 50 kOhm/12W resistor in series limits its current to 8 ma. The quartz lamp (5V, 10W) is also co-aligned with the fiber, so its light is very bright. The 4-mm thick BG38 color-balance filter is installed to equalize the intensity between red and blue wavelengths.

The electronics box contains a simple pulse generator for controlling the prism servo motor in the FEM, relays for switching the spectral lamps, logic, and the power supplies (12V and 5V). The DC/DC converter for the spectral lamp is powered by 12 V. The power switch on this box activates all the electronics. The control of the lamps, motor, and LED done by the data-taking software.

2.4 Acquisition and guiding

The guiding camera is GC650 from Prosilica. It has 659x493 square pixels, pixel size 7.4 micron (0.38 arcsec on the sky), field of view 3 arcmin. diameter. The signal depth is 14 bits (4096 counts). Minimum exposure time is 0.000001s (10 microseconds). The camera is powered by +12 V from FEM. Its digital signal is transmitted by a dedicated Ethernet cable to the guiding PC which is rack-mounted in the computer room. This PC runs under Linux, its name is `ctioxb`, fixed IP address: 139.229.12.62. The standard `PCguider` program runs on this computer.

3 CHIRON spectrometer: optics

3.1 Optical design

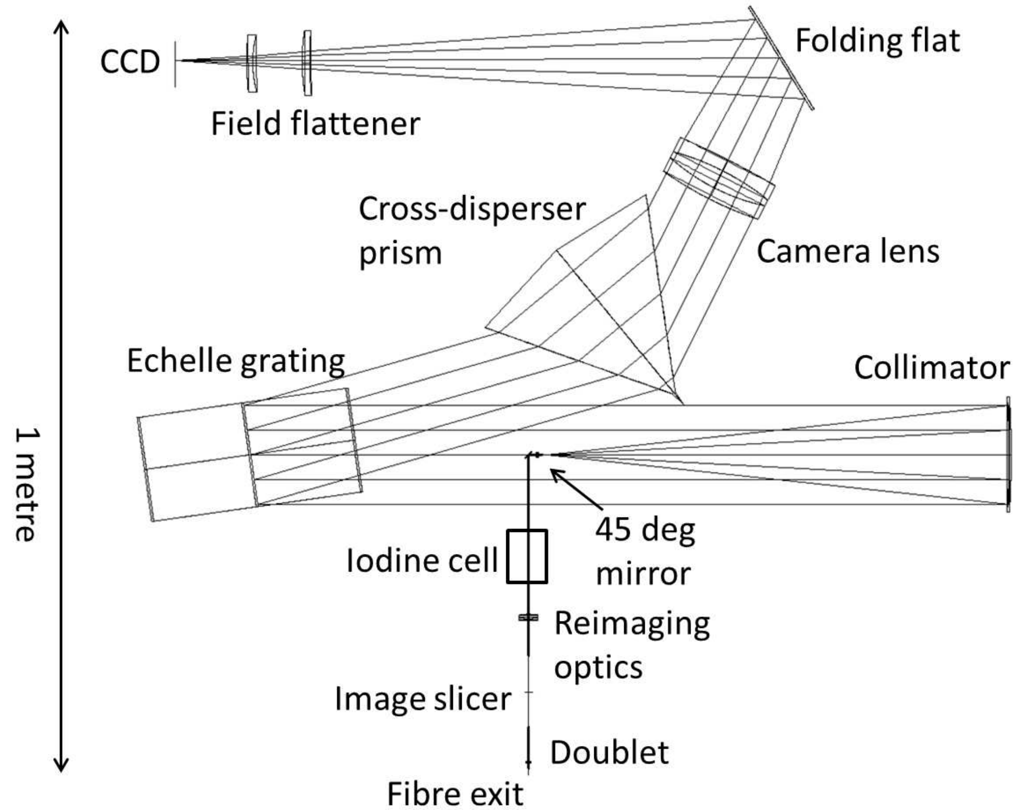

Figure 7: Optical layout of CHIRON.

Table 1: Optical elements of CHIRON

Function	Element, parameters
Main dispersion	Existing echelle 31.6gr/mm, blaze 63.5° 375x200mm
Cross-dispersion	LF7 prism, apex angle 62°
Collimator	On-axis parabolic mirror $F = 610\,\mathrm{mm}$, $D = 150\,\mathrm{mm}$
Camera	APO-140 apochromat & flattener $F = 1005\,\mathrm{mm}$ $D = 140\,\mathrm{mm}$
Folding flat mirror	$D = 150\,\mathrm{mm}$, Edmund Optics, custom coated
Detector	4096×4096 pixels of 15 μm size

Main optical elements of CHIRON are listed in Table 1. The incident and reflected beams are separated by tilting the echelle grating perpendicular to the incidence plane by $\gamma = 5.5°$. CHIRON is designed for a 4K CCD with 15 μm pixels. The spectral format is shown in Fig. 8.

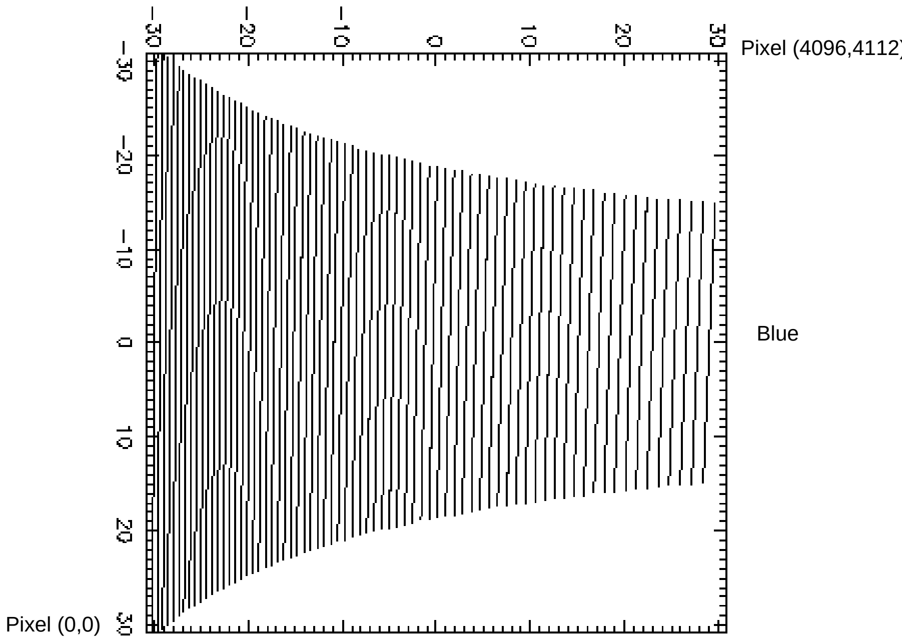

Figure 8: Spectral format of CHIRON covering the range 415–887 nm. The scale on the detector is in mm. Each line covers the free spectral range (FSR) in one order. The rightmost is order 135 (416–419 nm), the left line is order 64 (873–887 nm). The detector center corresponds to $\lambda = 526$ nm.

Table 2: Image relay optics

Element	Part number (EO)	Dist. next, mm
Fiber in FC connector	none	15.72
Lens L1, $F = 15$, $D = 6.25$	N47-691	90
Image slicer	Custom	95.92
Lens L2, $F = 100$, $D = 25$	N47-671	210
Diagonal mirror, 12.5mm	N45-754	10
Lens L3, $F = 12.5$, $D = 6.25$	N47-690	10.36
Collimator focus	none	609.6

3.2 The APO camera

The camera is a a commercial triplet lens APO-140 produced by Telescope Engineering Company (TEC, http://www.telscopengineering.com). This oil-spaced triplet lens has light diameter of 140 mm. The focal length with a 2-element field flattener is 1012 mm. The first-lens-to-detector distance is 1005.2 mm, the back distance is 94.2 mm. TEC has kindly provided the optical prescription, allowing us to evaluate the performance of the triplet lens. As shown in Fig. 9, the spot diagrams fit within 50 μm over the whole field of 42 mm radius (or 60x60 mm square), the maximum admitted by the

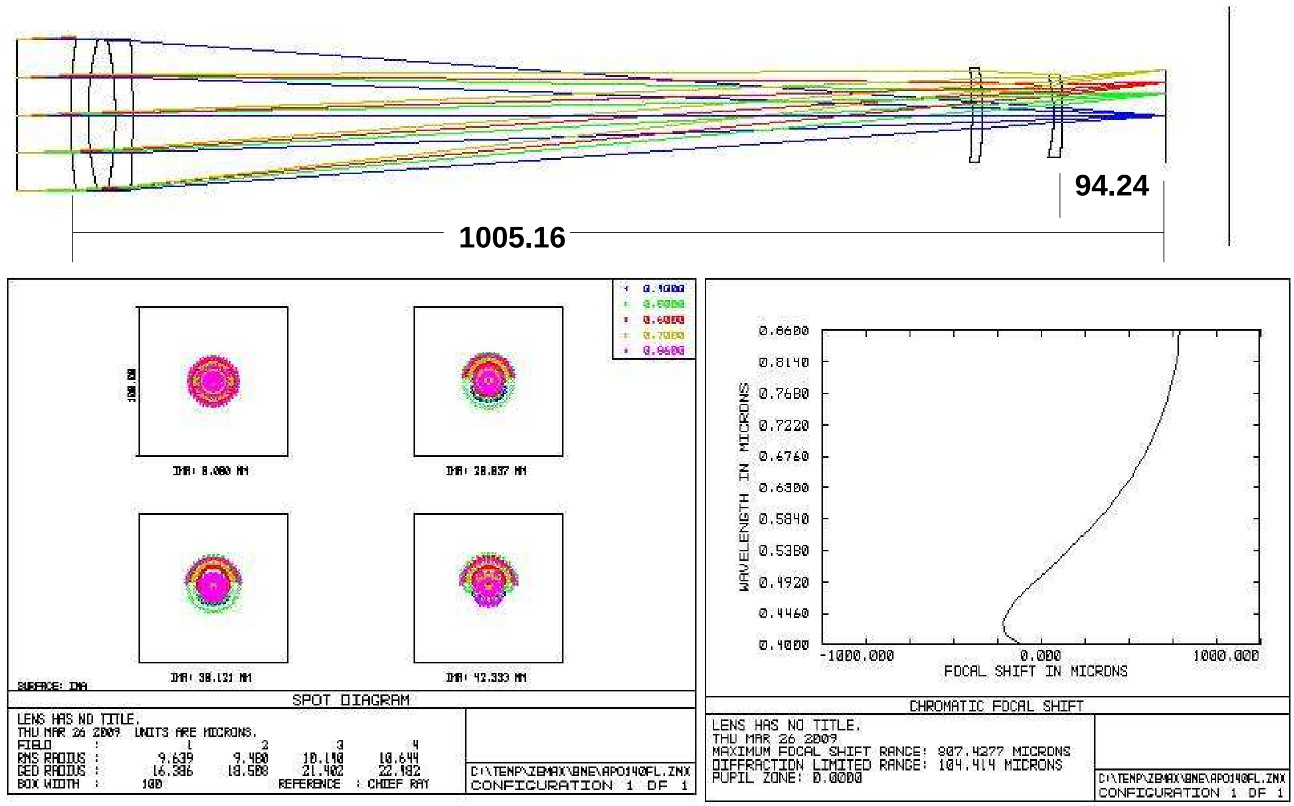

Figure 9: The APO-140 with field flattener. Layout and some dimensions (top), spot diagrams (left, box side 100 μm) and focus dependence on wavelength (right).

flattener. The major residual aberration is chromatic defocus, so the lens is diffraction-limited at any given wavelength. The triplet and flattener lenses have broad-band anti-reflection (AR) coatings, with a typical loss of 0.25% per surface.

3.3 Image slicer

CHIRON uses a Bowen-Walraven image slicer. For fabrication reasons, two mirrors replace the standard design with total internal reflection (Fig. 10). The incident beam falls on the mirror M1 with a sharp edge AA', passing near the edge BB' of another mirror M2. Part of the beam passes directly and forms slice #1. The remaining part is reflected upwards to the mirror M2 (which is parallel to M1), then back to M1. Again, part of the beam passes near the edge (slice #2). The rest bounces once more between the mirrors and forms the slice #3. A prototype has been built, it shows a nicely sliced image as expected.

To reduce defocus, the beam is transformed to a slow $F/28$ ratio. The fiber image is magnified 6 times, to $a = 0.6$ mm diameter. The gap thickness is then $h = a/\sqrt{2} = 0.42$ mm. The defocus of each slice $l_1 = 0.6$ mm causes a blur of 0.6/28=0.021 mm, negligible even after 2 bounces. The sliced slit image is 0.2x1.8 mm size.

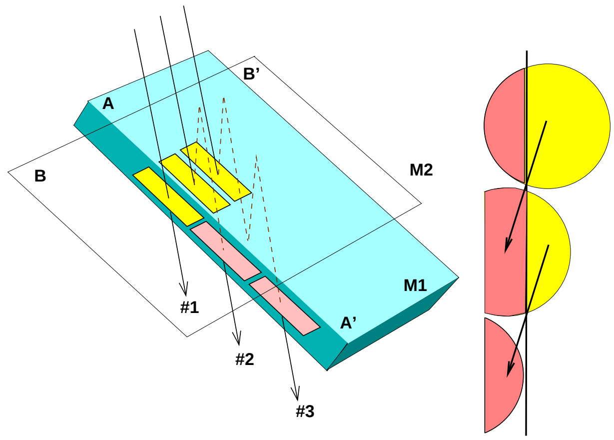

Figure 10: Optical concept of the reflective Bowen-Walraven image slicer.

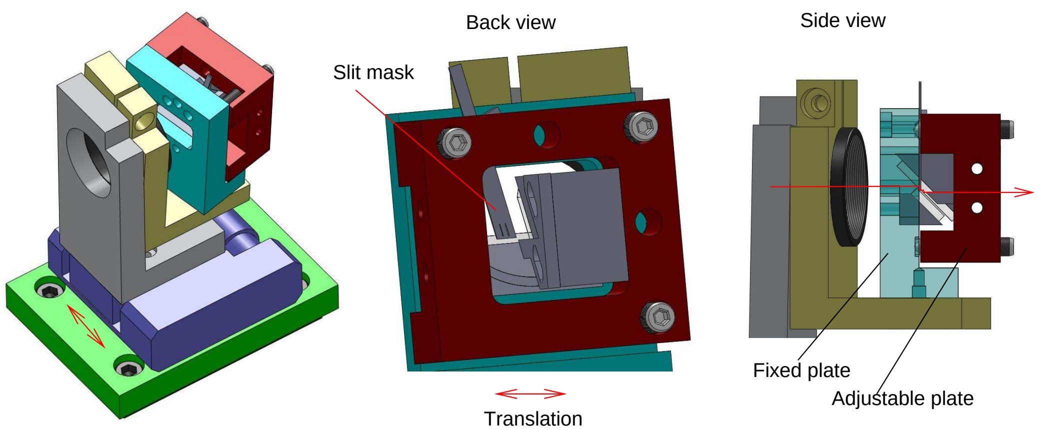

Figure 11: Mechanical design of the image slicer.

The image slicer is mounted on a linear translation stage (M-110.1DG from PI) with travel range 5 mm. Un-sliced fiber can be used by simply moving the slicing edge away from from the image. Further motion occults the fiber by a mask with two slits (width XXX and XXX). By selecting normal or narrow slit, we can take spectra with narrow (un-sliced) orders but high resolution, at a cost of the light loss (Fig. 12).

3.4 Fore-Optics Box (FOB) and viewer

Table 2 contains the optical elements of the image relay, from fiber to collimator. The beam emerging from L2 is collimated; it can go through the iodine cell without focus re-adjustment. The beam diameter is 3 mm for each image point, or 5.5 mm considering all points with a slicer.

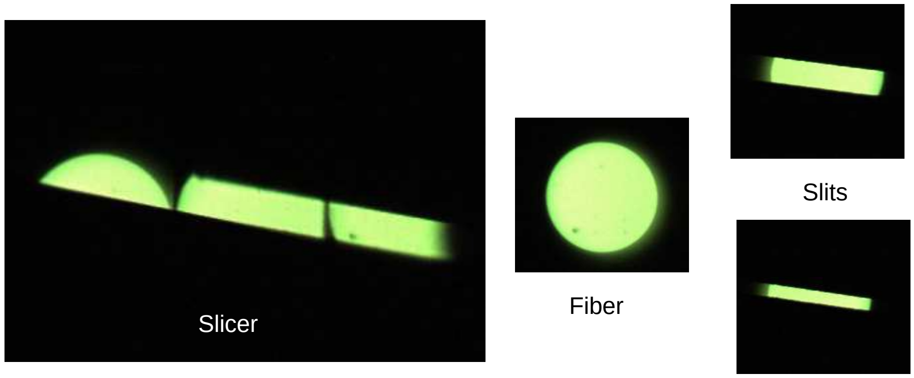

Figure 12: Images of the “slit” as seen through the viewer, with fiber illuminated by the quartz lamp. The position of the translation stage defines whether the fiber image is “sliced”, transmitted unchanged or masked by the slits.

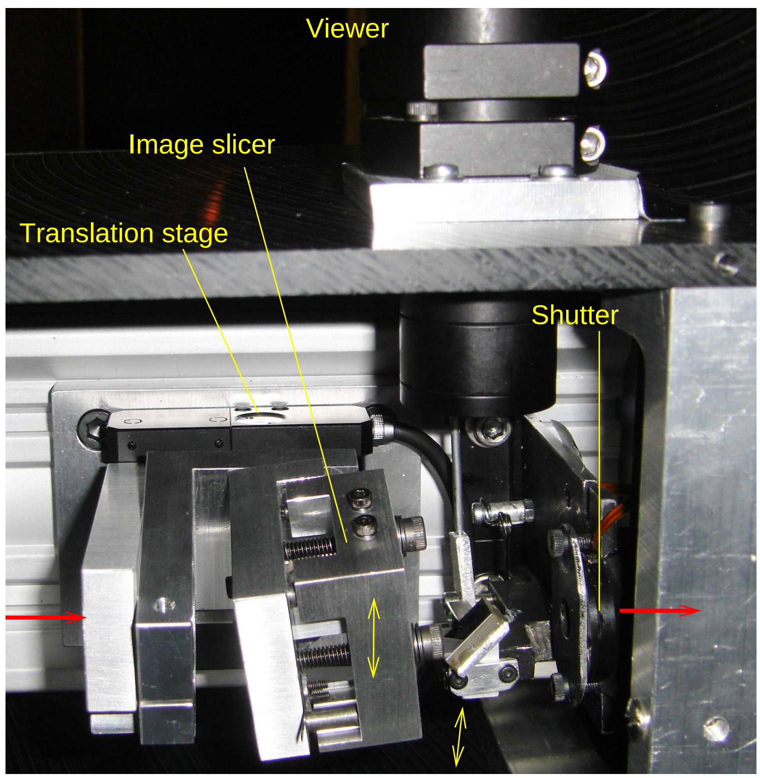

Figure 13: Image slicer and viewer. Red arrows show the light path from fiber to the spectrometer.

4 Mechanical design of CHIRON

CHIRON consists of the following main sub-systems:

- **Optical support structure** (OSS) holds together all optical elements in their respective mounts, in fixed relative position. The OSS consists of the standard optical table 90x75x11 cm and a rigid frame attached to it. The table is oriented horizontally.
- **Instrument support structure** (ISS) is an interface between the OSS and the external world. ISS interfaces to the enclosure (and is part of it). ISS holds the CCD dewar with field flattener.
- **Enclosure** protects CHIRON from light and dust. The environment inside the enclosure is stabilized in temperature.
- **Optical mounts** hold CHIRON elements such as echelle, collimator, collimator focal assembly (CFA), prism, triplet, fold mirror. All mounts are attached to the OSS.
- **Fore-optics box** (FOB) contains optical elements preceding the CFA: fiber connector, lens L1, image slicer, shutter. A flip mirror can be inserted manually to view the beam after the image slicer.

4.1 ISS and OSS

The ISS (dark green in Fig. 15) is a steel frame structure. It consists of two welded modules bolted together. The vertical frame is welded from the U-channel steel profile (2"x1", wall thickness 3/16"), the lower (horizontal) frame – from the 3"x3" square profile (wall thickness 1/8"). Two diagonals connect these parts in a stiff way.

The horizontal frame transmits the weight load to the ground through three stationary supports (when installed definitively) or through 4 wheels (during integration and transport). The OSS (optical table) attaches to the vertical frame at two points A and B, while its other end is supported by a vertical screw at point C, connected to the table at two points by a horizontal beam. The point A is close to the dewar, minimizing the image displacement on the detector caused by possible deformations of the ISS. Flexure of the ISS must not be transmitted to the OSS. Ideally, an un-constrained kinematic connection between the table and the ISS requires that the point A be fixed in all 3 coordinates XYZ, point B – in X and Z only, point C – in Z only. The actual system as designed constraints the connection at B in all 3 directions.

The vertical frame holds the dewar assembly and has a rectangular opening for the echelle box. The variable weight of the dewar is supported by the ISS, not by the OSS.

The OSS is based on the standard optical table of 90x75x11 cm size (English hole pattern and threads, PBH 12111 from Thorlabs). The optical axis is at 100 mm height above the table. Most elements are attached to the table using its hole pattern and/or clamps.

A Π-shaped structure, "bridge", is attached to the table. It is welded from the stainless-steel profile (U-channel) of 4"x2" cross-section, the wall thickness is 4.8 mm (3/16"). The two legs of the bridge are bolted to the table. Two diagonal members ensure bridge stiffness against bending moments. The bridge holds attachment elements for the echelle and for the fore-optics box (FOB) – the FOB plate. The latter connects to the OSS through the box-shaped structure bolted to the bridge.

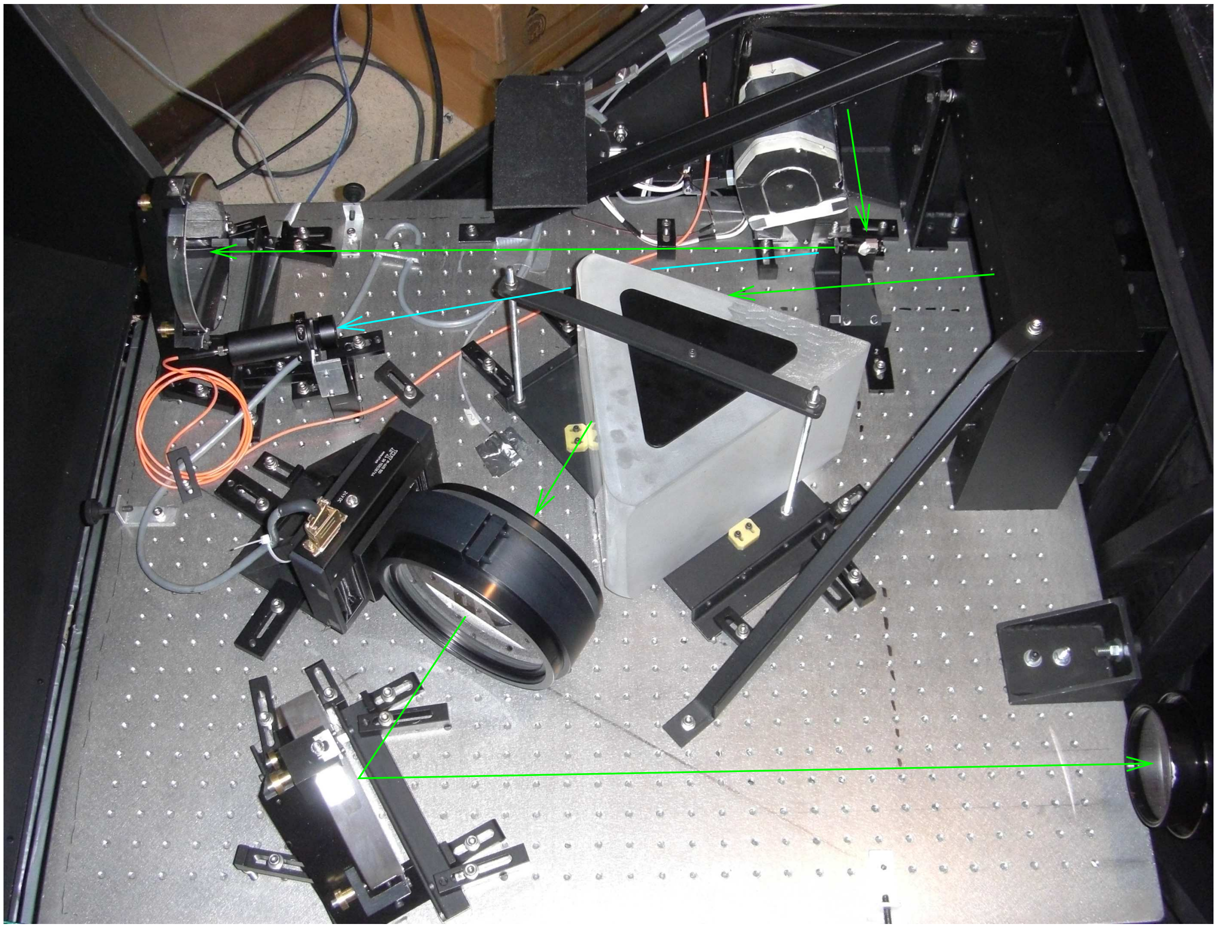

Figure 14: Picture of the CHIRON optical table. The main light path is traced by the green lines, the EM beam is light-blue.

4.2 Enclosure

The CHIRON enclosure consists of three parts (Fig. 16): an isolated part of the ISS (E1), a big box covering the table (E2), and a smaller box covering the echelle (E3). The three parts join by means of a foam seal, making an air-tight container. The size of E2 is 980x900x480 mm, the size of E1 is 500x450x400 mm.

The boxes are made of 1.6-mm aluminum sheet attached to the frame welded from aluminum profile. The frame has a smooth and rigid contact surface along the edge of the box. When the box is closed, it presses against bulb silicone seal[1], compressed to the 6-mm thickness. The box itself is hermetized with aluminized duct tape and silicone.

From the outside, the boxes are covered by a 1" thermo-insulating foam panels made from poly-isocyanurate. The foam is enclosed between thin metal foil on both sides, the cut edges are sealed with the duct tape. These panels can be easily detached from the box. The same panels surround the

[1]part No. 91241K921 from mcmaster.com

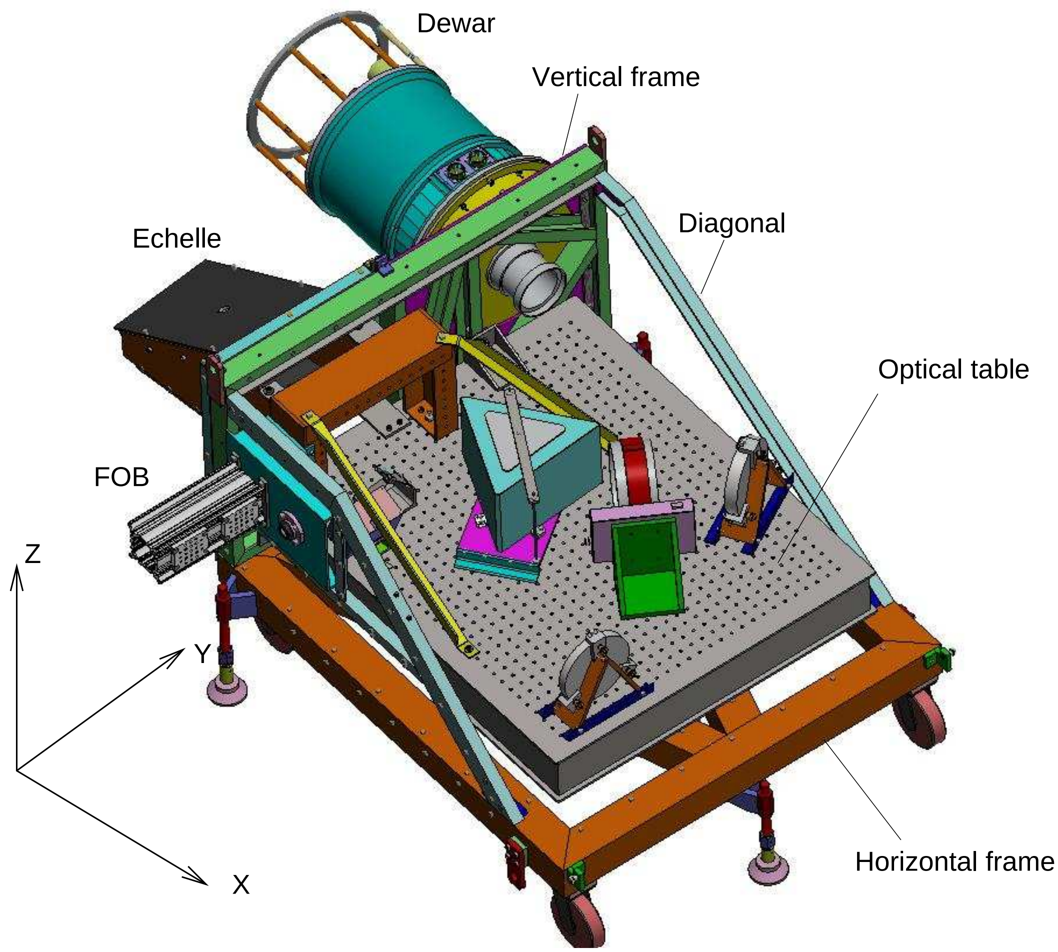

Figure 15: Overall CHIRON structure.

fixed enclosure part E1 and the non-hermetic box around the FOB, not shown in Fig. 16.

The rectangular gap between the plate which holds the FOB and the E1 wall is sealed with foam and duct tape. The FOB space is not hermetized, the light goes inside CHIRON through the lens L2 which acts as a seal. The exit port (towards the CCD) is hermetized by the field-flattener lenses, dewar base and the plastic wall. Aluminum panels close the E1 part on both sides below the diagonals and below the table. Electrical connectors are located on the triangular E1 panel near the FOB.

The box E2 is attached to the ISS by two hinges along its lower edge, so that it can be conveniently opened. The hinges can be disconnected for a complete removal of E2, if needed. The E3 is simply pressed with 4 screws near its corners.

The lower aluminum panel of E1 is heated by three silicone heating strips [Part No.] glued to it. The heater is controlled to stabilize the CHIRON internal temperature at few degrees above ambient air.

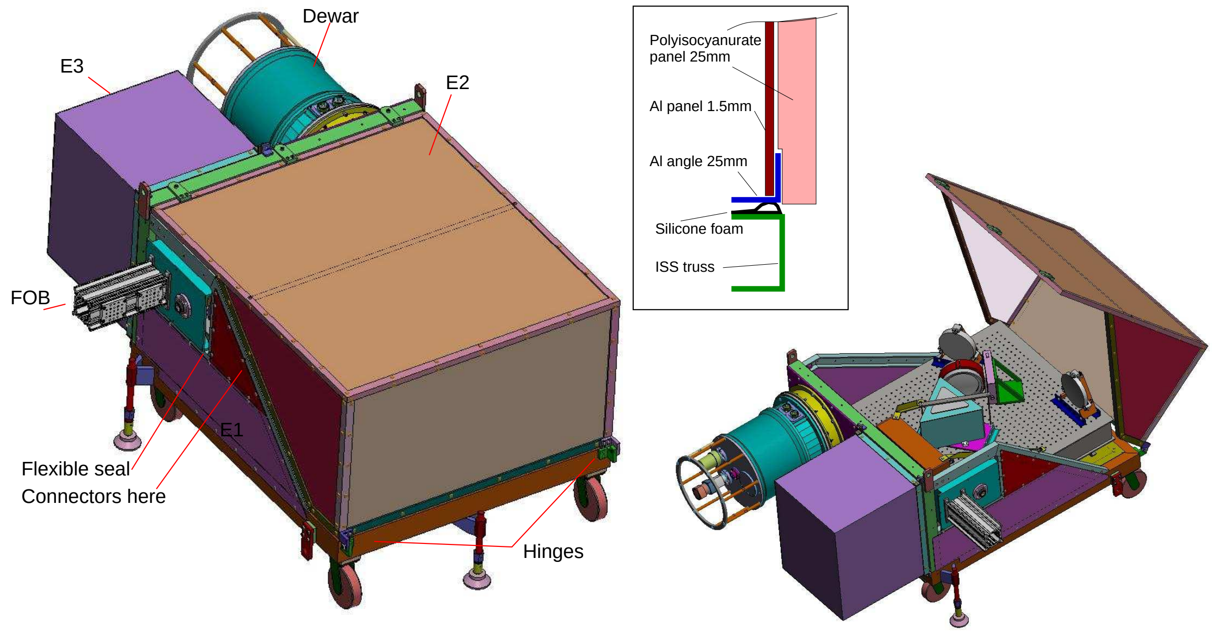

Figure 16: The enclosure. The scheme shows the air-tight interface to the ISS in cross-section, the picture on the right shows the opened enclosure.

4.3 Dewar attachment

The CCD dewar is a cylinder of 312 mm diameter and slightly larger length. The mounting flange has outer diameter 360 mm, the CCD surface is 9.32 mm behind it, with a 9-mm fused-silica window, AR-coated. The back side of the dewar is protected by a ring, making the whole dewar length equal to 510 mm. The LN2 tank volume is 5.4 l.

The dewar mount consists of two main pieces (Fig. 17): the base (gray) attached to the ISS and the flange (yellow) to which the dewar (blue) is bolted. The flange can be adjusted w.r.t. base in tilts and roll angle, then firmly fixed.

The base has outer diameter of 380 mm. It is pressed to the plastic plate (1/4", black delrin, green color in Fig. 17) which connects it with the ISS with several screws. The plastic provides thermal and electric insulation of the dewar from the ISS. Slightly over-sized holes allow small lateral adjustment during the assembly. The union is hermetized with black silicone. Therefore, the plastic plate seals the inner space of CHIRON from air and light. Differential thermal expansion between the steel ISS and the aluminum base is expected; the resulting stress will be alleviated by the plastic between these elements.

The dewar flange fits inside the base, centered by a thin "collar" with matched diameter and an O-ring near it. This allows for tilts and rotation (roll). Once the adjustment is done, the two parts are pressed together by 8 clumping plates, as shown in the cross-section (both parts are slightly deformed by clamping, removing residual gaps). Initially, the clamps are free. The tilts of the flange are regulated by means of 3 push and two pull screws, the roll – by an adjuster at the side of the cylinders. The dewar can be removed and installed without perturbing the tilt/roll adjustment.

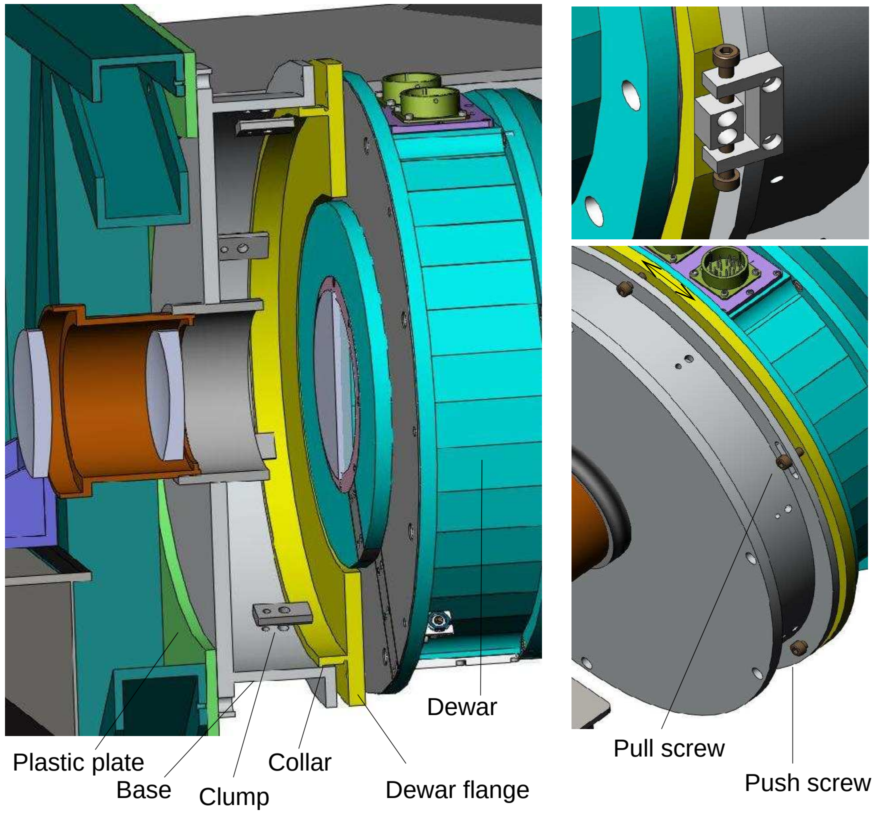

Figure 17: Dewar alignment.

The field flattener is screwed into a 100-mm cylinder which, in turn, is screwed into the base. This allows for an air-tight connection and provides for some axial adjustment of the field flattener. The space between the base and the dewar flange is almost sealed, a small container with desiccant is placed there to prevent dew condensation on the dewar window.

4.4 APO mount and focusing

The APO-140 triplet is mounted in a steel cylinder of 168 mm diameter (with 172-mm outer rim) and 76 mm length. The edge of the front lens is at a depth of ≈ 16 mm w.r.t. the front edge of the cylinder. The back end of the cylinder has an internal thread. The design of the APO-140 mount is shown in Fig. 18. For focusing, the triplet is moved axially by few mm under remote control, using a commercial translation stage M-605.1DD from Physik Instrumente. The translation range is 25 mm. The stage has a load capacity of 20 kg axial and 10 kg lateral. The resolution is 0.1 μm, accuracy 1 μm, pitch and yaw stability $\pm 30\,\mu$rad. Considering that the optical axis is at $\sim$100 mm from the stage, the latter number translates to $\pm 3\,\mu$m lateral shifts, or 1/5 of the CCD pixel. The APO steel cylinder is clamped by a split ring which is bolted to the stage, with a thin interface plate in-between. The stage, in turn, is mounted on the table by means of a bracket.

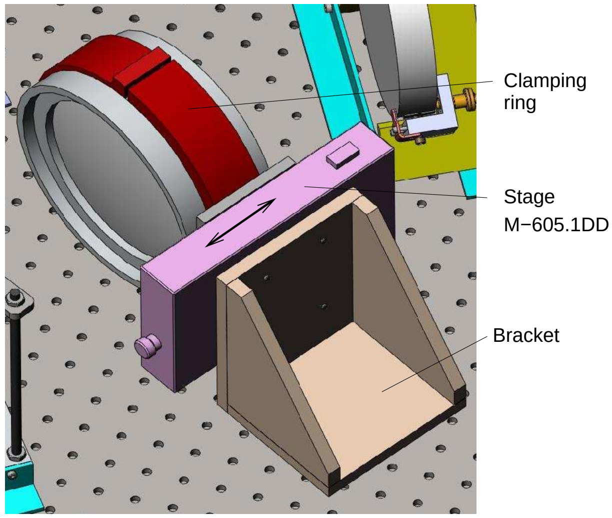

Figure 18: APO mount on the table, focusing.

4.5 Prism mount

The prism is big and massive. Sides 260 mm (around apex) and ∼275 mm (base), height 160 mm, estimated mass 10 kg. Considering that the glass homogeneity on one side of the blank is not good, the beam center should be at 75-mm height above the good side, leaving 80 mm distance to the other (bad) side.

The prism rests on three plastic pads glued to the 8-mm thick base plate of 270x160 mm size. Lateral position of the prism is defined by three adjustable thick plastic stops which press against polished sides without vignetting the beam. The prism is pressed against the plate by the upper triangular plate with 3 plastic pads and the steel bar screwed to the base-plate with two long rods. The elasticity of the bar and triangular plate provide adjustable clamping force.

The base plate is attached to the table with two steel angles. The angle of the prism (in cross-dispersion direction) and its position are adjustable by moving the mount on the table, then clamping it. The prism position is "memorized" by 3 adjustable stops on the table, permitting to dismount and re-install it reproducibly.

4.6 Echelle mount

The echelle grating blank has size 375x205x51 mm, its estimated mass is 11.5 kg. The echelle is mounted in a rectangular box of external dimensions 400x222x65 mm, with some protruding parts and cover. The position-defining points are 3 pads pressed against front echelle surface, two lateral hard points on the long side and one lateral hard point on the short side. Bronze leaf springs press opposite to each hard point.

The design takes maximum advantage of the existing grating mount The mount is complemented by two 8-mm "walls" on both sides which are connected by a plate, forming an "echelle box" with a rectangular cross-section. The vertical plates are attached to the OSS at 4 corners. The whole assembly is oriented with the echelle looking down.

The attachment of the echelle box consists of two 6-mm steel plates bolted to the table and two steel angles bolted to the bridge. To adjust the echelle angle in the γ-direction (cross-dispersion), the box is rotated in the horizontal plane, using two screws as an axis. The other pair of screws passes through elongated holes. The pivot point of γ-tilt is at a distance of ~ 30 cm from the grating center, so the adjustment causes acceptably small lateral motion of the beam on the grating (5 mm per 1°). The grating angle β in the dispersion (blaze) direction is adjusted by tilting the mount inside the walls, then fixing it firmly by lateral screws. The grating angles γ and β remain fixed during CHIRON operation. **Give gap values in the aligned state.**

4.7 Collimator focus assembly (CFA)

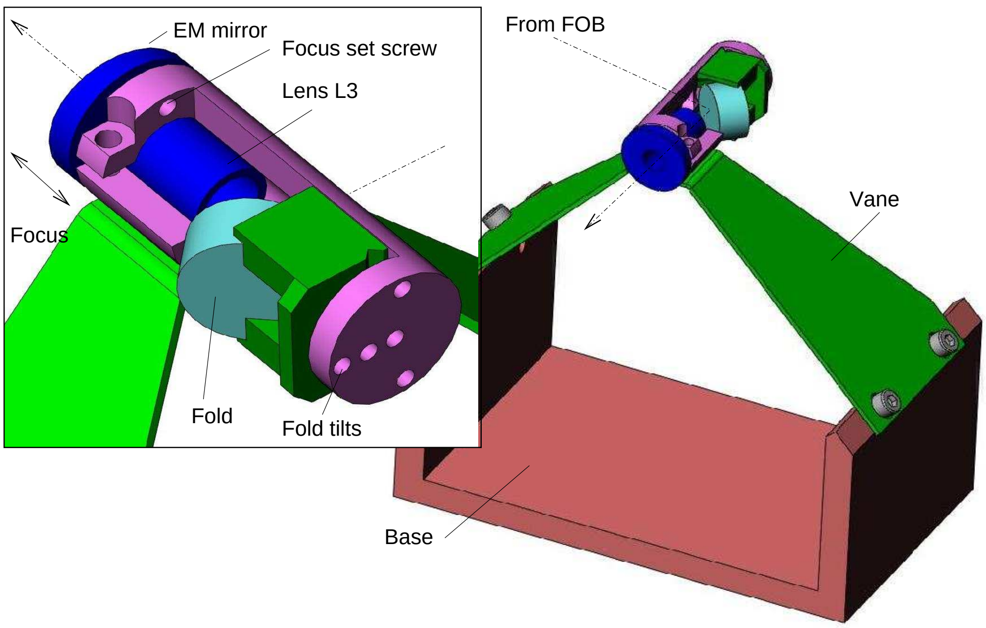

Figure 19: Collimator focus assembly.

The CFA module includes a small (12.7-mm) mirror to turn the beam by 90°, a focusing lens L3 ($F = 12.5$ mm, $D = 6.25$ mm), and a flat mirror with a 1.5-mm hole. This latter mirror intercepts the central part of the collimated beam (which would be obscured anyway) and sends it back to the exposure-meter. All three elements are assembled in a unit with a small footprint (to reduce the beam obstruction) and suspended at the center of the collimated beam. The design (Fig. 19) implements this with two steel vanes (thickness 1 mm) at 40° from the vertical. The vanes are fixed to the base (U-channel steel profile 4"x2") which, in turn, is clamped to the table. The vanes are made of a single plied steel sheet, its central part is bolted to the circular body of 15 mm diam. During assembly, the central body and the base are fixed at correct position (100 mm above the table, parallel) while the vanes are not yet attached. Then the lower ends of the vanes are fixed (the holes in the vanes are elongated).

The lens L3 is glued in a barrel of 8 mm diameter which slides axially inside a matching channel for focusing in the range ±1 mm (pressed against a set screw), then clamped. It is easy to remove and put back the L3 barrel. The front surface of the barrel is machined at 5.5° angle to its axis. A thin mirror with a hole at the center is glued to this surface to reflect the light for the exposure-meter. The reflection angle is fixed, but its azimuth can be regulated by rotating the barrel.

The folding mirror (12.7 mm diameter, 6 mm thickness) is glued in steel holder which can be adjusted in tilts by means of three set screws and one pulling screw (the screws are not shown in Fig. 19). The adjustment screws are easily accessible. Note that the mirror is excessively thick, its protruding part which increases the footprint is cut.

There is an on-axis hole in the back wall. Once the mirror is removed, this hole can serve for the initial alignment of the CFA body, using a thin laser beam to trace the axis. Then the mirror is installed and aligned to reflect the beam at correct angle and position.

4.8 Collimator and fold mounts

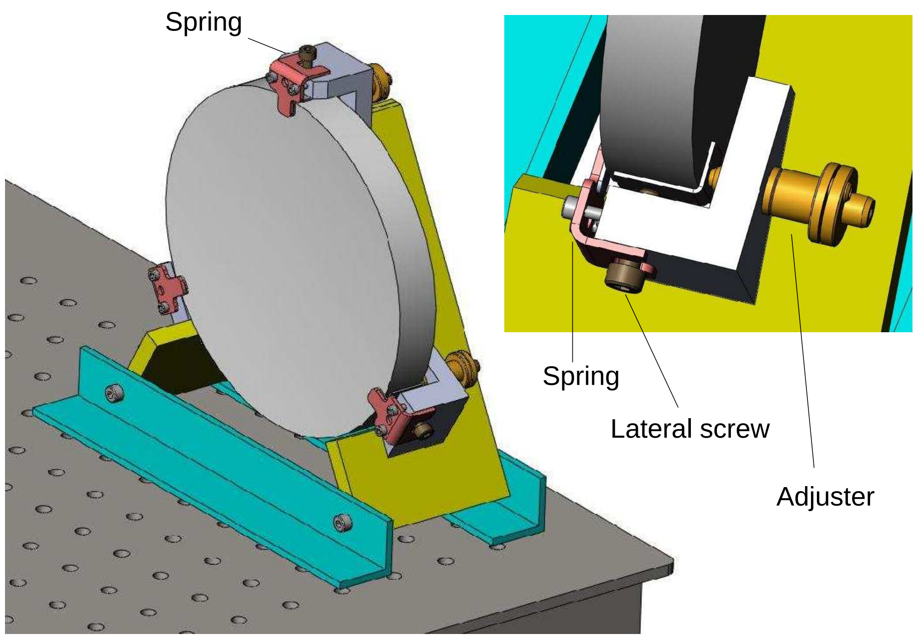

Figure 20: Design of the collimator and fold mounts.

The collimator mirror has diameter 152 mm, edge thickness 17.5 mm. The fold mirror is also 6" diameter, with 1" (25.4mm) edge (Edmund Optics, N48-125). The mounts for both elements are similar (Fig. 20). The optics is held by three right-angle units attached to the pair of aluminum ribs. The ribs are bolted to two steel angles which are clamped to the table. This design has low thermal stress.

The holding unit is detailed in the insert of Fig. 20. The most critical axial adjustment is provided by the commercial fine-pitch screw AJS100-02H (Newport) with clamp. The range is about ±0.3 mm. The mirror is pressed axially by a leaf spring, with an adjustable force. The lateral position is defined by two standard M4 screws on the two lower units and by a spring in the upper unit.

A common problem of all mirror mounts is friction. Once the optical element displaces slightly, the spring pressure tries to bring it back in contact with the hard point, but the support friction in the perpendicular supports reduces the restoring force, causing hysteresis or even preventing the spring action. To avoid this, the hard points and springs could be "floating" in the perpendicular direction. A simpler method is to reduce the friction by putting a thin Teflon sheet between the glass and the hard points. We adopt this approach and place a small steel angle between screws and glass, separated by a Teflon film from the glass. This separating element can be removed or modified without changing the main design. The leaf springs also have small Teflon pads; in addition, they are not very stiff laterally and can "float".

4.9 Iodine cell container

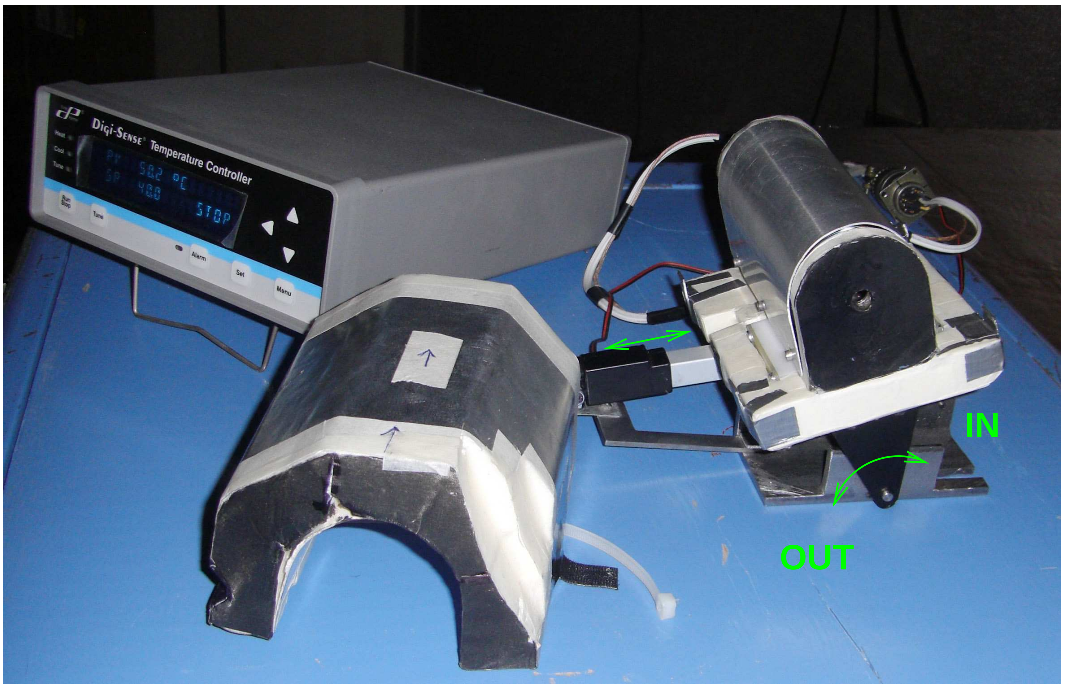

Figure 21: Photograph of the iodine cell container and its actuation mechanism. Part of the thermal insulation is removed. The Cole-Parmer temperature controller is in the background.

Iodine cells are glass cylinders of 40-50 mm diameter and maximum length 114 mm, with a small "finger" on one side. The cell is maintained at uniform stabilized temperature (nominally +45°C). It is placed in a heated aluminum box (Fig. 21). The heater element (Arcol power resistor, 1.2 kOhm, 10 W) and the temperature sensor are in thermal contact with the box and stabilize its temperature. The container is surrounded by thermal insulation (thickness 6-25 mm), leaving only small (8 mm diameter) windows for passing the light. The length of the box with insulation along optical axis does not exceed 140 mm. The heating power is typically about 5 W.

The container is attached to the mechanism of its in-out motion by two fiberglass plates to minimize the heat conduction. The height and parallelism to the table are adjustable. The in-out mechanism consists of an axis oriented parallel to the beam and a linear actuator (Firgelli model L12-30-100-12-S). The axis rotates in a simple base (steel U-channel, 2"x1") clamped to the table. For servicing, the whole unit (including its electrical connector) should be removed from the CHIRON.

4.10 Hartmann mask

The Hartmann mask is used for checking the focus. It can cover upper or lower half of the collimator beam. The mask is operated manually, by inserting a hex key in the 1/4 20 TPI screw protruding from the connector panel. The mask must be retracted after its use!

4.11 Exposure-meter feed

The EM feed consists of an achromatic lens ($D = 25$ mm, $F = 85$ mm, EO) in a 30-mm (SMA1) Thorlabs tube with focuser. The SMA fiver connector is placed at the other end of the tube. The assembly is placed at 100 mm height from the table to intercept the central 15-mm part of the collimated beam reflected from the CFA mirror. The angle of the tube is adjustable to match the fiber with the actual beam. The adjustment is done by injecting light in the SMA fiber and placing its image on the slicer.

5 Electronics

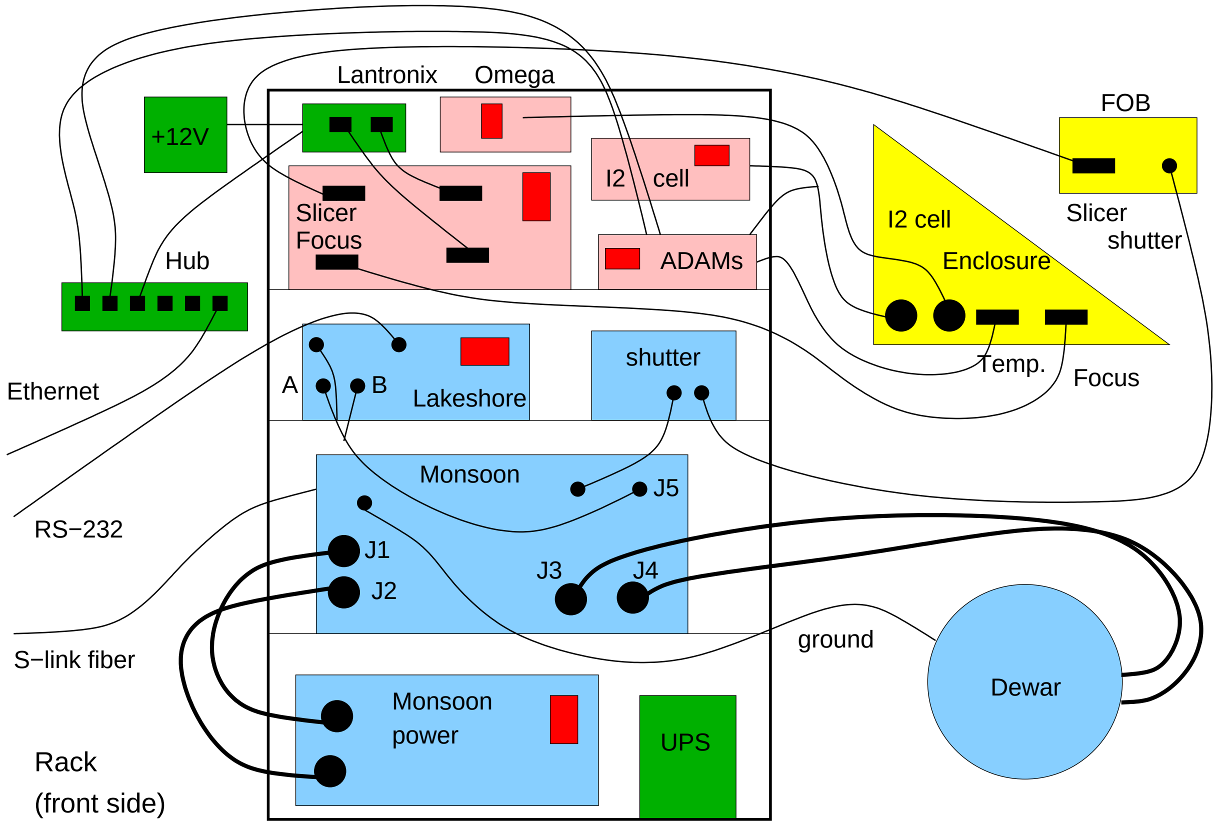

Figure 22: CHIRON connections. Color coding: blue – detector system, pink - other electronics, green – service modules, yellow – CHIRON, red – power switches. Connections to 110V power are not shown.

Only a general overview of CHIRON electronics is given here. More detailed information is found in specific documents and electronic diagrams. The FOB electronics has been briefly covered above. CHIRON electronics located in the coude room (mostly inside the rack) can be sub-divided into the detector system (Monsoon CCD controller, Lakeshore temperature controller and shutter box), motion control, temperature control and monitoring, and service. Overall connections are shown in Fig. 23, the photograph of the rack is given in Fig. 23.

5.1 Detector system

The dewar is electrically insulated from the CHIRON, but connected to the Monsoon with a special grounding cable, as well as through its two cables. The electronics rack is grounded through the 110V power line. Monsoon is switched on by its power supply, but the Lakeshore controller must be switched separately. The TTL shutter signal generated by the Monsoon is wired to the shutter driver (model Uniblitz ED12DSS) located in a separate box and powered by +12V [TBC]. The shutter itself

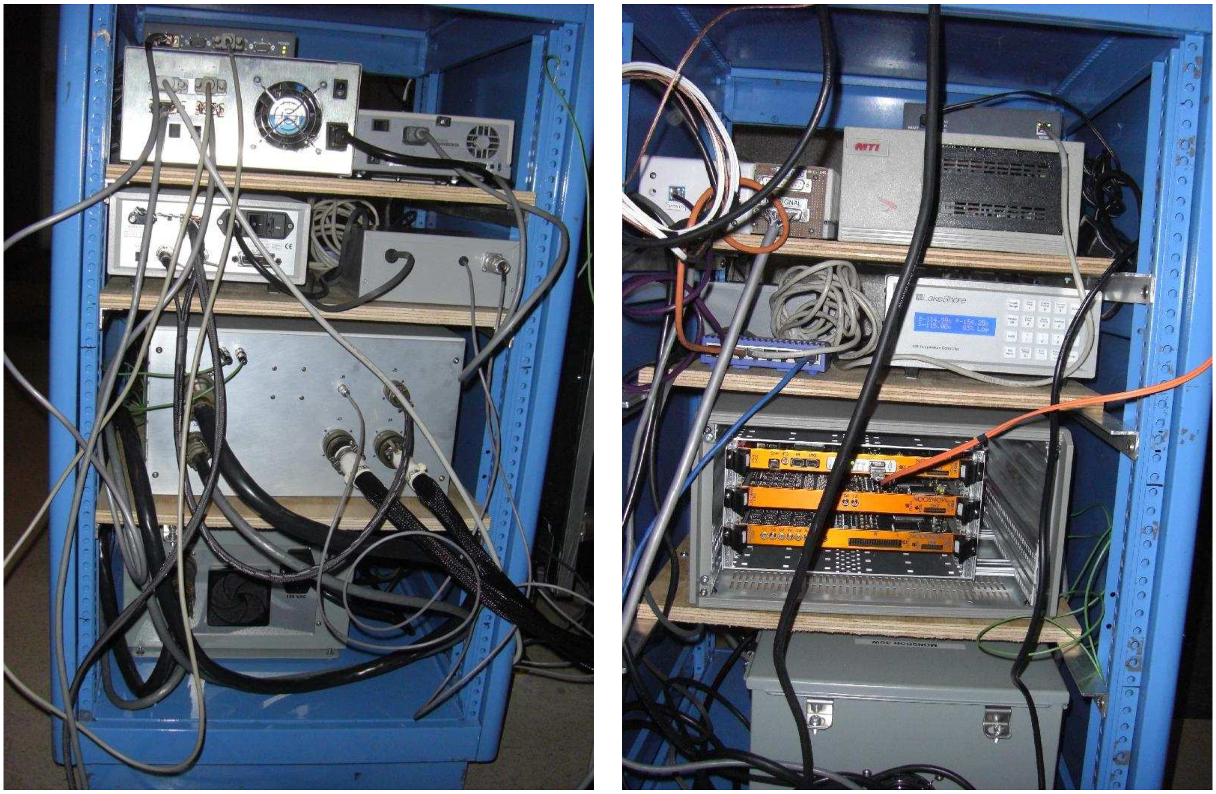

Figure 23: Photographs of the CHIRON rack (left: front side, right: back side).

is located inside FOB.

5.2 Motion control

The slicer and focus stages with servo motors (from Physik Instrumente) are controlled in a similar way using EZSV23 single-board controller from allmotion.com. However, the focus stage M-605.1DD was incompatible with this controller because it contains internal power amplifier for the motor. The problem was solved by opening the stage and wiring the motor directly to the pins of the DB15 connector. Both motors and their controllers use the +12V power. The serial connection to the controllers is through network, using Lantronix EDS4100 Ethernet/RS232/485 adapter. Only Lantronix two ports are used at present, the other two are available.

The vendor prohibits motor connection in the powered state. Always turn off the motor-control box before disconnecting or connecting the motors, **do not hot-plug!**. After power-on, the motors should be initialized to start reading absolute positions. However, the control software remembers the motor positions, therefore the encoder readings are still valid even after a power outage [TBC].

The Firgelli linear actuator for iodine cell in/out motion is controlled by the polarity of its 12V power: it simply moves between two states depending on the polarity. The motion is commanded by a logical (TTL) signal derived from the Ethernet ADAM module, using a small interface circuit. This electronics is located in the “ADAM box”. The motor is connected through the cable used for the iodine-cell temperature control.

5.3 Temperature monitoring

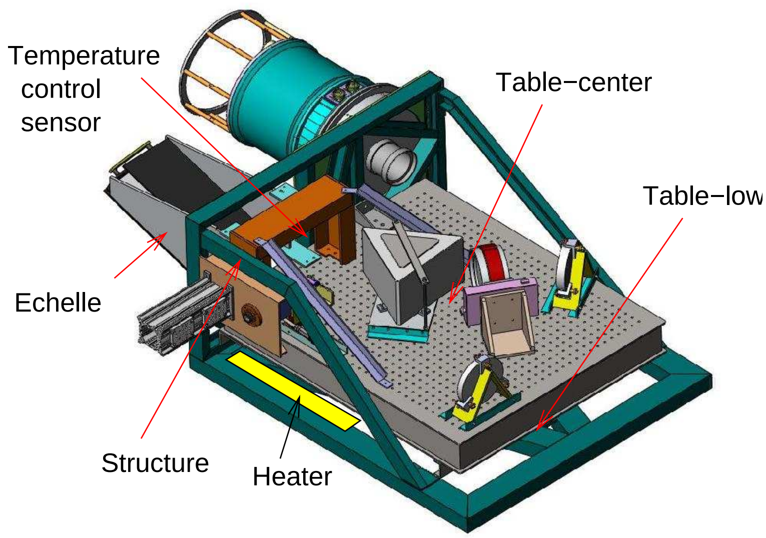

Figure 24: Locations of the temperature monitoring sensors and temperature control sensor (red arrows). One heater element out of three is also shown.

Temperature at various points inside CHIRON and in the ambient air is monitored by the 100-Ohm RTD platinum sensors from omega.com. The signals are wired to the DB25 connector at the CHIRON panel, then by a 25-way 1:1 cable to the ADAM module. The 7-channel ADAM-6015-BE Ethernet module reads the sensors. [More information: ref. to document]. The sensors 1 to 5 correspond to echelle mount, optical table (center), room air, optical table (low), and ISS, as shown in Fig. 24. Small individual offsets between the sensors are calibrated out in the software, so that equal readings correspond to equal temperature, to within $\pm 0.1^\circ$ [TBC].

5.4 Temperature stabilization

Internal temperature of CHIRON is stabilized by regulated heaters. The heating elements are silicone rubber heating strips (110V/45W each, size 1"x18" - part 35765K154 from mcmaster.com). Three such strips are glued to the aluminum panel of the enclosure below the optical table (Fig. 24). The space between the panel and the table is insulated by a foam sheet to prevent table heating from below and bending.

The CNi8 controller (model CNi822-C4EI from omega.com) with Ethernet interface is used to control the heater. As the output relay of CNi822 is rated for only 0.5 A current, a more powerful 10A SSR (model A1210 from CRYDOM) is used to drive the heater. The temperature is sensed by a 100-Ohm RTD glued to the ISS.

The temperature **in the coude room** was stabilized during 2010 by an oil heater (1.6kW/110V, De Longhi) and an adjustable temperature switch (part 3626K44 from mcmaster.com), with its sensing

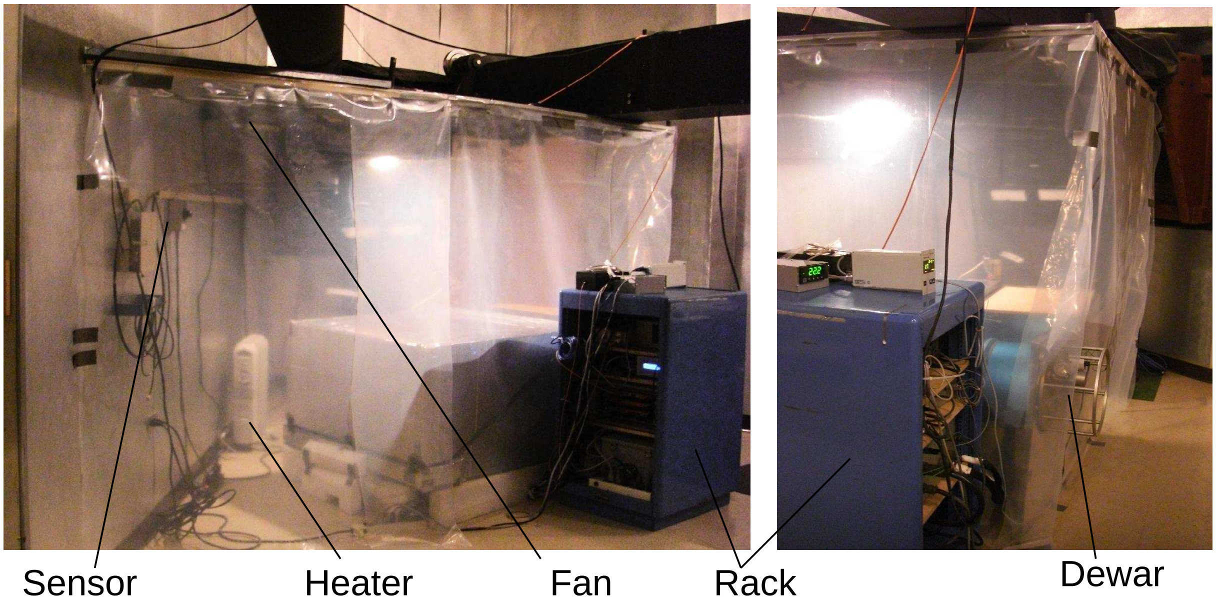

Figure 25: Pictures of the plastic curtain around CHIRON ("warm room") and elements of its temperature stabilization. The electronic rack and N2 exhaust from the dewar are outside the controlled environment.

element hanging from the wall. In May 2011 the space around CHIRON was insulated from the reat of the coude room by a plastic curtain and fake ceiling (Fig. 25). A fan attached to the ceiling (model Silenx SX-120 25-11 from Ixtrema, 12V DC power) forces air circulation, blowing in the direction of the dewar corner. The dewar filling hole and electronics rack are outside the temperature-controlled space.

5.5 Heating of the iodine cell

The iodine cell contains a 10-W power resistor and a thermocouple sensor (type K). These elements are connected to the Cole-Parmer temperature controller (model 89000-00). The cell is permanently maintained at +45°C, even when not used.