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PRIMET integration and alignment procedures

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Author(s):	N. Schuhler/S. Lévêque Name	Date	Signature
WP Mgr:	F. Delplancke Name	Date	Signature
Head of Division:	R. Gilmozzi Name	Date	Signature

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1 Scope

In this document the alignment plan for the laser metrology system of PRIMA, PRIMET, is presented. The procedure for aligning the system is divided by subsystems and in the chronological order in which it will be integrated at Paranal.

2 Applicable and Reference Documents

The following Applicable and Reference Documents (RD) contain useful information relevant to the subject of the present document.

Table 1. Applicable and Reference Documents

Nr	Doc Nr	Doc Title	Issue	Date
RD1	VLT-SPE-ESO-15731-3884	Test of the laser frequency stabilization system of the PRIMA Metrology System	1.0	26/06/06
RD2	VLT-TRE-ESO-15730-4042	PRIMA Metrology test report	1.0	02/04/08
RD3				

3 Definitions

p-polarization	linear polarization state parallel to the uv plane (plane of the PRIMA table)
s-polarization	linear polarization state parallel to the w axis (perpendicular to the uv plane)
(gaussian) beam radius	the metrology beam as a gaussian profile, in this document the radius is always considered for the peak intensity divided by e

4 Acronyms

BC	Beam Combiner
BS	Beam Splitter
IR	InfraRed
PBS	Polarizing Beam Splitter
MM	Multi-Mode (optical fibre)
SM-PM	Single-Mode Polarization Maintaining (optical fibre)

5 Introduction

6 PRIMET laser frequency stabilization

6.1 Prerequisites

The following tasks must be completed to integrate the laser frequency stabilization:

- the laser head and the 75/25 fibre coupler must be installed and operational;
- PRIMET control electronics must be integrated and operational.

6.2 Laser focus

The 1.319 μm laser beam must be focused in the nonlinear crystal to generate the second harmonic beam at 659.5 nm. The theoretical optimal focusing parameters are recalled in Figure 1 (for more details see RD1).

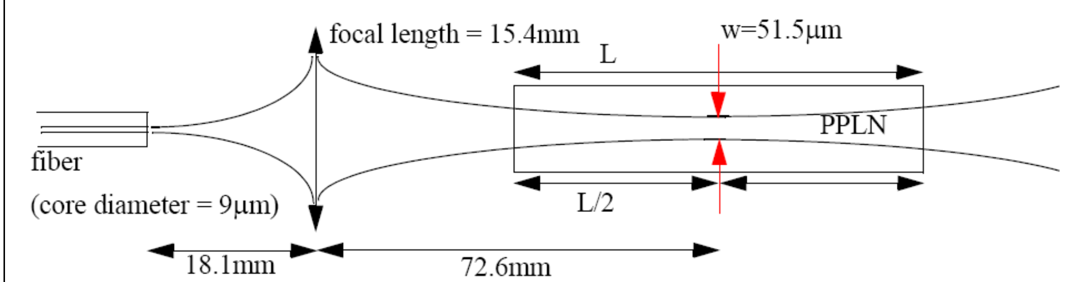

Figure 1: laser beam focusing in the nonlinear crystal, w is the waist diameter (at 1/e), L is the crystal length and PPLN stands for Periodically Poled Lithium Niobate

The distance between the fibre end and the focusing lens is set so that the beam waist is approximately located 72mm away from the lens. In that configuration the beams waist should be 51.5 μm diameter which can be verified roughly with the beam profiler (the laser beam intensity on the detector must be dimmed by using optical densities in order to avoid damaging the detector of the beam profiler).

6.3 Crystal alignment

The crystal is aligned so that the waist of the beam is located at the centre of the crystal. Fine alignment of the crystal is done when the crystal temperature is stabilized at 47.5 °C. A silicium photodiode can be used to monitor the power at 659.5 nm and optimize both the alignment and the focus of the IR beam in the nonlinear crystal. After optimization, the conversion efficiency (power in the IR divided by the power at 659.5 nm) should reach at least 2.4×10^{-4} for an IR power of 50 mW.

7 PRIMET injection/extraction optics alignment procedure

At the output of the fibres the beams are collimated with an achromatic doublet to enable the use of a visible laser for the alignment. However, all the procedures requiring the monitoring of the fringes detected by the phasemeter must be done with PRIMET infrared laser (as the detectors are in InGaAs)

7.1 Prerequisites

The following tasks must be completed to integrate the injection/extraction optics:

- The infrared laser head and heterodyne assembly must be installed and operational (the frequency stabilization is not required);
- The laser interlock system must be integrated and operational;
- The fibre optics for injection (SM-PM) and extraction (MM) between the storage room and the optical lab must be installed;

- MARCEL and FSU A/B warm optics must be integrated and aligned with respect to the VLTI (not required for the collimation and coalignment of PRIMET optics but mandatory for its alignment on VLTI);
- IRIS IFO dichroics must be installed;
- WPRIMA workstation, lprmpd LCU installed in storage room, pmpsd installed on WPRIMA/lprmpd

7.2 Beams collimation

Step by step procedure:

- an OFR plate is mounted on the PRIMA table;
- the beamprofiler detector (Thorlabs BP-104 IR) is mounted 1 m in front of the OFR plate;
- the 8 OFR fibre ports are prepared, at least two of them must have the connector keys parallel to the uv plane and two others parallel to the w axis; these four are connected to SM-PM fibres, the four other ports are connected to MM fibres;
- two targets are mounted on the OFR plate to define a reference axis.

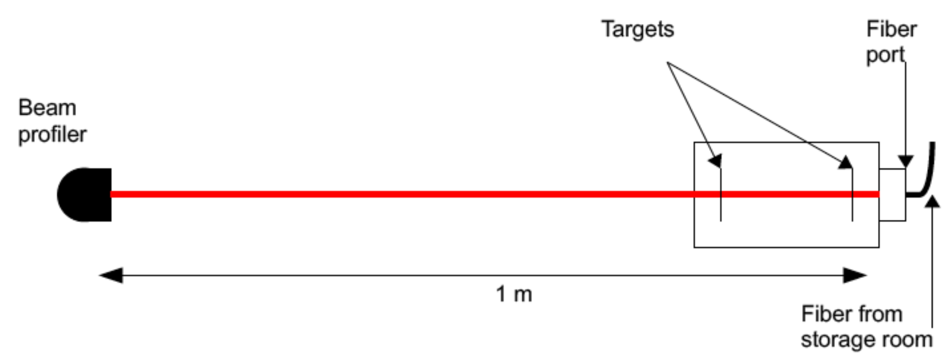

Figure 2: collimation of the fibre ports, the radius of the gaussian beam is measured after 1 m of propagation and should be 0.97 mm.

For each of the 4 fibre ports connected to SM-PM fibres:

- the OFR fibre port is mounted on the OFR table so that the light will propagate along the reference axis defined by the two targets and toward the beam profiler detector;
- the PRIMET infrared laser is switched ON;
- the beam is aligned on the two targets using the two tip-tilt screws (see 8);
- the beam profiler detector is aligned on the laser beam;
- the fibre port focus is tuned until the beam radius (considered at 1/e) at 1 m is 0.97 mm (theoretical value, see Figure 3);
- the PRIMET laser is switched OFF.

This procedure is repeated for the 4 fibre ports connected to SM-PM fibres. The morphology of the beam can be checked qualitatively at a longer distance using an IR viewing card or the IR viewer.
The 4 fibre ports mounted with MM fibres are collimated using a spare SM fibre. After the collimation the SM-PM fibre is replaced by the final MM fibre.

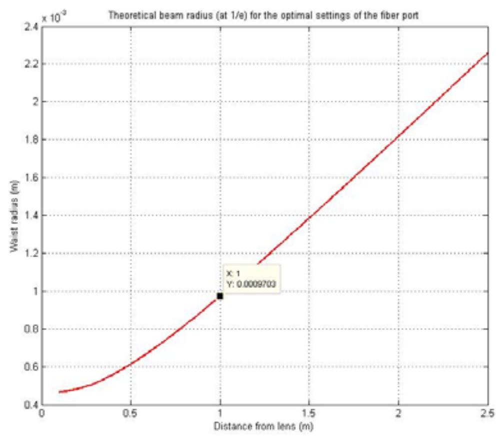

Figure 3: waist radius (m) at 1/e of the metrology beam as a function of the distance from the collimating lens (m) for a single mode fibre with core radius 4.5 μm

7.3 Metrology beams coalignment

- Preparation of the setup

The 4 fibre ports connected to SM-PM fibres are mounted two by two on their final OFR table. The configuration of the OFR table is described in Figure 5. Both systems should be identical to preserve the symmetry of the two FSUs. The fibre port should be mounted with the y translation screw of the lens on top for an easy access. In front of each fibre port a single pair of holes should be available before the position of the PBS. Two pairs of holes should be available in front of the position that will be used by the reference signal extraction fibre port. The PBS and the two linear polarisers are then mounted. A target is placed at the end of the OFR table to create a reference optical axis.

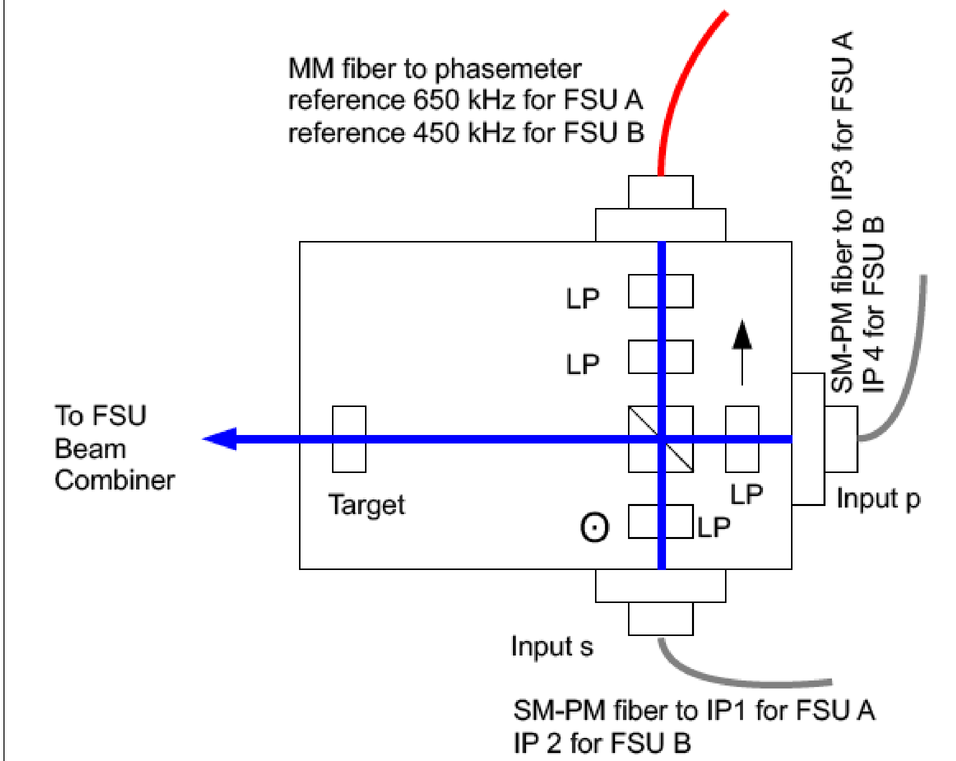

Figure 4: PRIMET injection optics plate configuration

Comment [Samuel Le1]: La figure apparait bizarrement...

- Coalignment of the two beams at long distance

Assumption: at the level of the PBS the two spots are superimposed
Step by step procedure:

- the p-polarization (transmitted) beam is aligned on the axis defined by the linear polarizer in front of the fibre port and the target at the end of the OFR table;

- the p-polarization (transmitted) beam is then used as a reference to align the s-polarization (reflected) beam; the coarse tuning can be done with the PBS, the fine tuning is done with the tip-tilt screw of the s-polarization fibre port;

- fine coalignment is done by visually superimposing the two spots at a long distance (for example, a 3 mm displacement between the two spots at 10 m would correspond to a tilt of approximately 1 arcminlab) or by using the centroid measurements on one beam profiler for the two beams (the beam profiler accuracy is 50 microns, at 1.5m this corresponds to a tilt error of 6 arcsec lab).

The coalignment can be refined by optimising the contrast of the fringes detected by the phasemeter.

Step by step procedure

- Optimization of the fringe contrast

- the reference fibre port is mounted on the OFR table with a linear polariser in front of it in the pair of holes closest to the PBS;
- the linear polariser is rotated until its axis is oriented at $\pi/4$ with respect to the uv plane;
- if the coalignment of the two beams has been done properly, a beat signal should be visible at the heterodyne frequency corresponding to the FSU. If no beat signal is visible, the connection of the AOM and the transmission coefficient of the AOM must be checked. If the detector is saturated, a second linear polariser is mounted behind the first one and rotated until a beat signal is visible;
- the contrast of the fringes monitored on the oscilloscope is optimized by rotating the first polariser to balance the power of the two incident polarization states;
- the contrast of the fringe can also be optimized by tuning slightly the tip-tilt of the reflected beam.

The procedure is applied to both injection blocks.

7.4 Alignment on FSU/Marcel

7.4.1 Coarse alignment on the BC central obscuration patch and on MARCEL retroreflectors

The injection blocks are mounted on the East side of their respective FSU in the area reserved for the metrology as can be seen in Figure 5 and Figure 6.

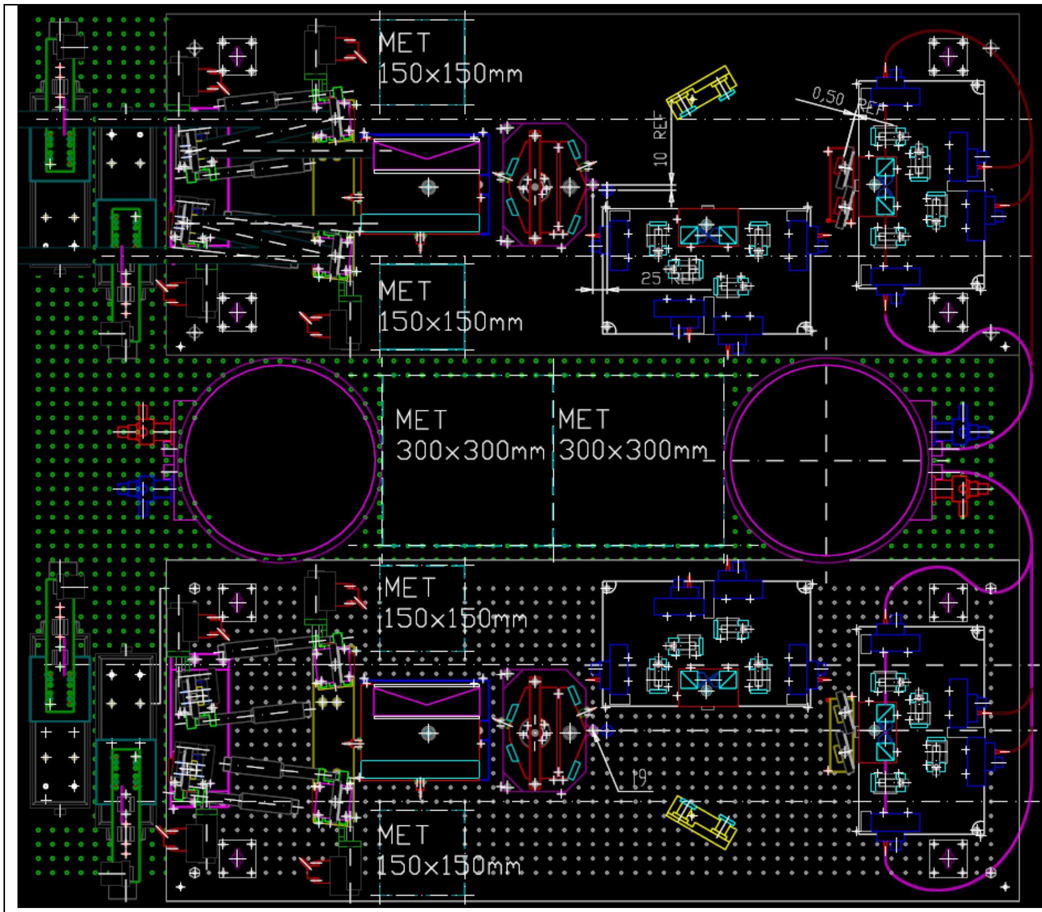

Figure 5: PRIMA table plan North is right.

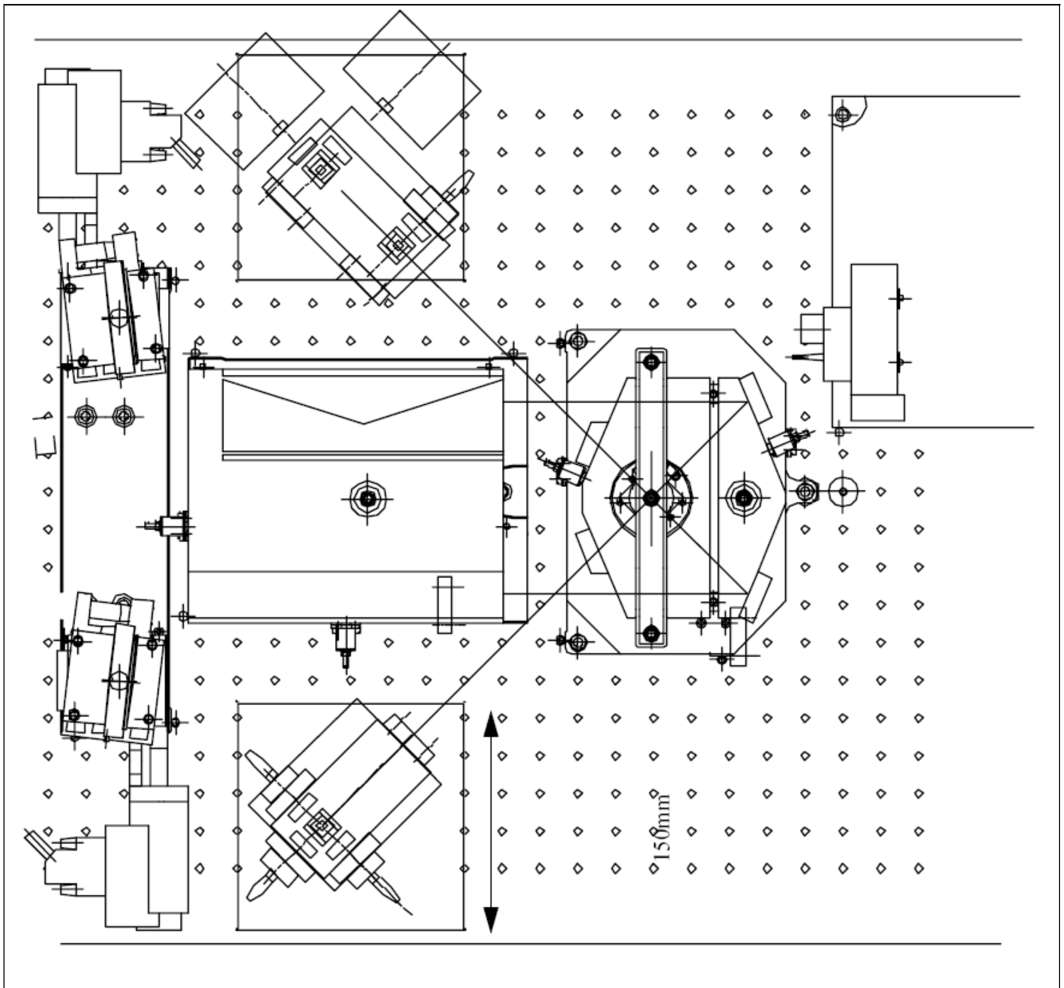

Figure 6: PRIMET injection/extraction optics on the FSU breadboard

Preliminary procedure:

- Marcel's black body is switched on and set to 600 °C;
- IRIS feedind optics are used in dichroics mode;
- The Marcel feeding optics are set in Autotest for the corresponding FSU (FSU A Ip 1 and 3, FSU B Ip 2 and 4);
- BTK is used on each beam to optimize the injection;
- The black body is switched off and Marcel is used with the visible laser diode;

Comment [Samuel Le2]: Which switchyard ?

Step by step procedure:

- MARCEL is used with a visible laser diode;
- the metrology beam is aligned on the axis defined by the BC central patch and the central obscuration of the beams coming from MARCEL; the injection block is recursively translated and tilted. The lateral

translation is used to align the beam on the central patch of the BC while the tilt is used to align at long distance the metrology beam inside the central obscuration of the MARCEL beams.

- due to the divergence of the narrow metrology beam, the spot radius at the level of MARCEL is approximately 17 mm (when using infrared light). Therefore, light may be retroreflected even if the beam is not perfectly centred on the corner cube (aperture diameter is 8 mm). The alignment should be verified visually with a viewing card provided there is enough power.

7.5 Alignment of the extraction block

The extraction block is located on the west side of its FSU at the same level as the injection block.
Step by step procedure:

- the end of the extraction fibre is connected to a visible light source to create a counter propagating beam;
- this beam is aligned on the axis defined by the central patch of the BC and the spot created at the level of the extraction block by the metrology beam returning from MARCEL;
- the extraction fibre is disconnected from the visible light source and connected to the phasemeter; the signal on the phasemeter detector is monitored on the oscilloscope and is used to refine the alignment by optimizing the flux injected in the fibre;
- a screen is placed just in front of MARCEL to check that the signal detected by the phasemeter drops to 0 and is not caused by a parasite reflection;
- any parasite back reflection must be cancelled out by vignetting on the fibre, if it cannot be achieved the surface responsible for the reflection must be identified and slightly tilted if possible (as it was made in the fringe tracking testbed for the FSU A K prism, RD2).

7.6 Cross-talk minimization

The procedure is described step by step for FSU A. It is exactly the same for FSU B.

- The beam of the s-polarization is blocked at the exit of the fibre port;
- The beam in the p-arm of the interferometer (beam transmitted by the BC) is blocked just after the BC;
- The DC voltage of the probe 650 kHz detector is monitored on the PMACQ panel or on the oscilloscope; ideally this voltage is 0.0 V;
- The parasitic signal is decreased as much as possible by translating the injection optics block while checking that the beam remains in the BC central obscuration;
- The parasitic signal is then decreased by rotating the injection plate using the goniometer; as the axis of rotation of the goniometer does not coincide perfectly with the optical axis, every rotation of the goniometer must be compensated for by translating the whole injection block;
- After minimization, the voltage $U_{p\ in\ s}$ is measured and noted down;
- The beam in the p-arm is unblocked and the beam in the s-arm is blocked, the voltage $U_{p\ in\ p}$ is measured.
- Apply the same procedure to the s-polarization, measuring the voltages $U_{s\ in\ p}$ and $U_{s\ in\ s}$.

Comment [Samuel Le3]: si on a bloque “s” en sortie du port OFR(1 iere etape), on aura pas de signal a 650kHz?

Comment [Samuel Le4]: pmacq

Comment [Samuel Le5]: est-ce que ce point est necessaries on fait le suivant?

- Calculate the cross-talk amplitude $A_s = U_{s\ in\ p} / U_{s\ in\ s}$ and $A_p = U_{p\ in\ s} / U_{p\ in\ p}$; the amplitude of the error created by the cross-talk is at maximum:

$$\delta l = \frac{2\rho}{2\pi}\frac{\lambda}{2}$$

where ρ is equal to the maximum of (A_p, A_s).

7.7 Pre-alignment of the quad cells

Assumption: the extraction block has been aligned successfully and the FSU are aligned on MARCEL
Step by step procedure:

- The quad cells are mounted on the extraction block and connected, after 30 min warm up time, the backgrounds are calibrated;
- the p-polarization beam is blocked just after the fibre port;
- the corresponding quad cell is aligned by maximizing the intensity seen on the detector, the value of the displacement delivered by the software cannot be used as the beam is vignetted (due to the limited size of the BC central patch);
- the s-polarization beam is blocked after the fibre port and the p-polarization beam is released;
- the quad cell corresponding to the s-polarization beam is aligned.

7.8 Alignment on two AT-STS, alignment of the quad-cell

Prerequisites:

- MARCEL is aligned on VLTI;
- FSU and PRIMET are aligned on MARCEL;
- The two STS are aligned on the VLTI, the corresponding M12 mirrors are configured in dual-feed mode

As MARCEL is assumed to be aligned on the VLTI and as PRIMET should be aligned on MARCEL at this time, PRIMET should be aligned on the VLTI. However, due to the large size of the spot of PRIMET on the MARCEL corner cubes, the alignment may not be optimised. Therefore, the alignment could be checked and refined (if necessary).

Step by step procedure:

- a sighting scope is mounted on the reference plate located before the switchyard and aligned on the VLTI;
- PRIMET is fed with a visible laser instead of the IR laser;
- PRIMET beam tilt is adjusted using the sighting scope as a reference and the lateral position is tuned using the BC central patch as reference.

Step by step procedure for the quadcell alignment:

- The beam profiler detector is inserted before the extraction block and the diameter and shape of each returning beam are checked;
- The size and shape of the beams are optimized by tuning the DL VCMs radii of curvature;

- For each beam, the pupil lateral position is scanned along a grid using the STS-VCM to determine for which position the injection in the extraction fibre is maximized (as can be seen on the PMACQ panel) (Apply spiral search?);

Comment [Samuel Le6]: using the STS-VCM?

- The optimal offsets found previously are applied to the VCMS and the quad cells are aligned on the returning beams using PMPSD panel;

- The conversion matrix from $[x,y]_{\text{quad cell}}$ to $[u,v,w]_{\text{light duct}}$ is measured. A script sends to the STS VCM LCU a series of offsets in the coordinate system of the light duct. The STS VCM LCU transforms them into the coordinate of the VCM and applies the command to the VCM. The corresponding movement of the spot on the quad cell is recorded simultaneously. A Matlab script is used to read the data and compute the conversion matrix.

8 Annex A: PRIMET injection/extraction optics, OFR ports

The injection and extraction optics of PRIMET are the same. They are composed of an OFR fibre port made of a fixed fibre connector and of a 5 mm focal length lens mounted on a magnetic plate. The plate can be rotated in tip-tilt and translated along the optical axis with two sets of three screws mounted in a push-pull configuration. This allows tuning the focus and the lateral position of the beam. Moreover the lens can be translated with respect to the fibre end with two orthogonal screws in order to tip or tilt the beam.

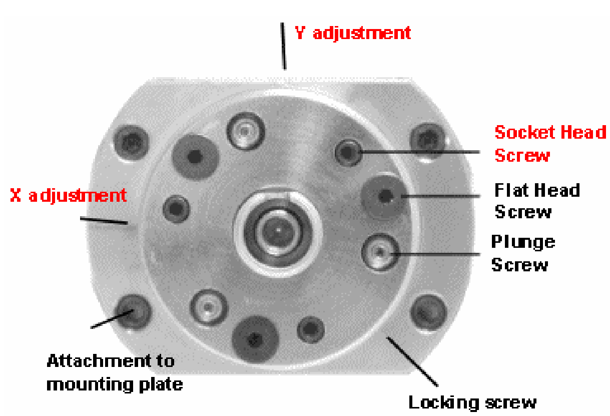

Figure 7: OFR fibre port; the x and y adjustment screws allow to change the tip/tilt of the beam; the socket head screws and plunge screws are mounted in a push/pull configuration which allows to focus the beam (and with a very limited range to change its lateral position).

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