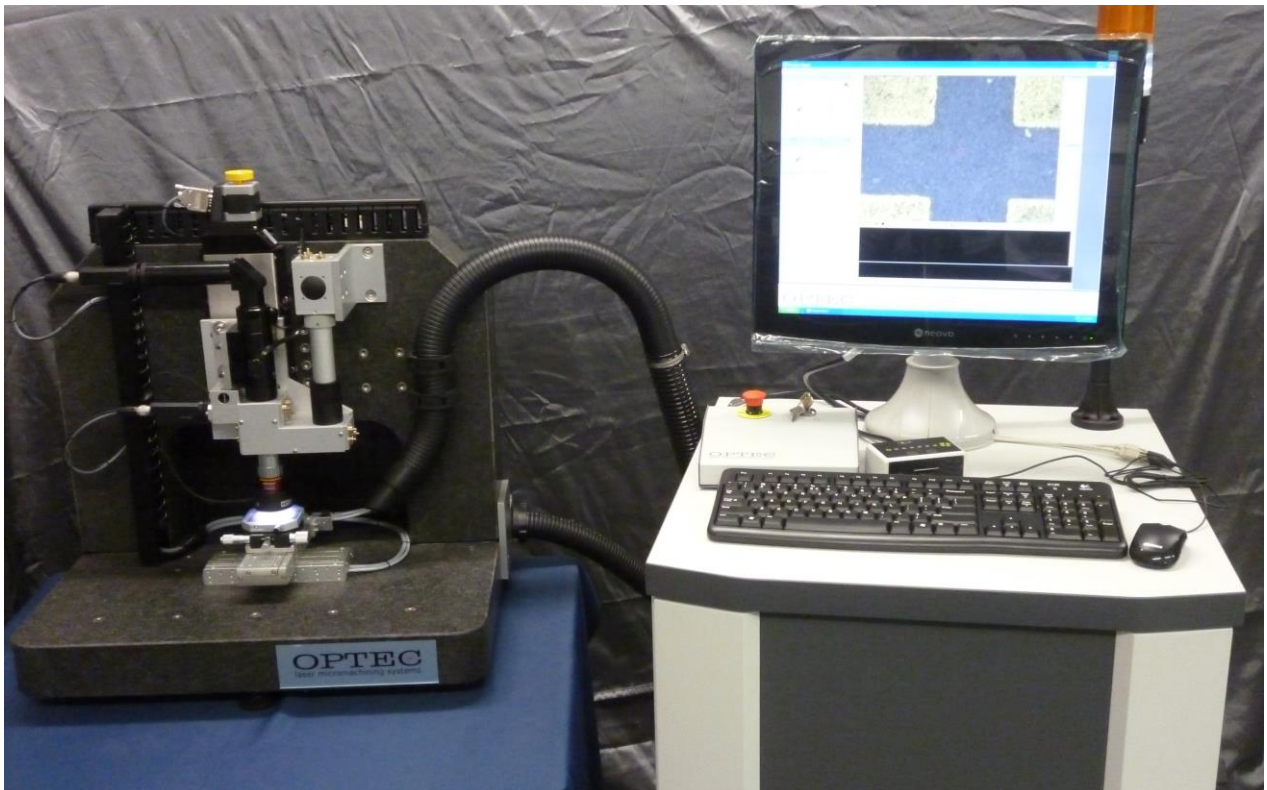


IIT Kanpur BDU

USER INSTRUCTIONS



OPTEC
laser micromachining systems

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IIT KANPUR BDU- USER INSTRUCTIONS

The Optec IIT Kanpur BDU is a Beam Delivery Unit (BDU) intended for use with 1550/775nm IR laser and includes part motion, vision systems, and operating software. The opto-mechanical assembly is intended to be mounted on an optical table, and when combined with a suitable laser source will form a complete laser micromachining system. This IIT Kanpur BDU manual is to read in conjunction with component-specific manuals. **Optec recommends that you study these manuals BEFORE using the machine.**

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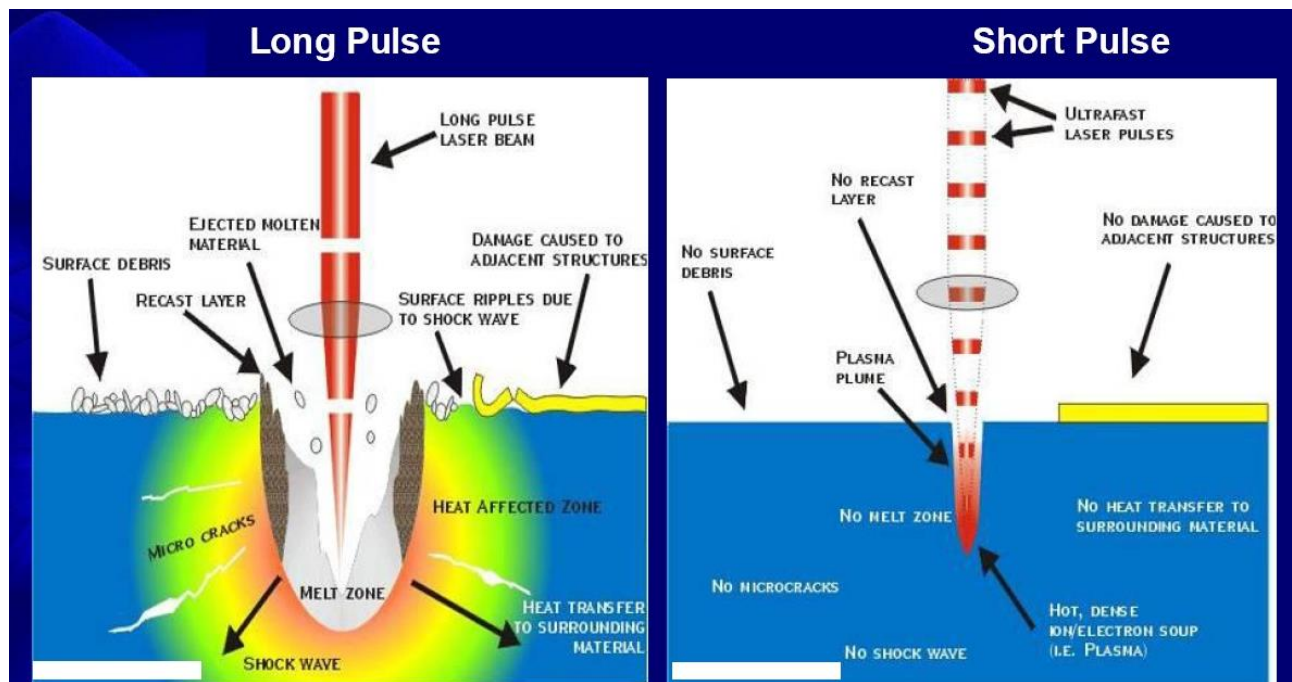
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1 BASICS

1.1 Short Pulse Laser Machining

Short pulse duration ensures that material at the laser focal point is melted & vaporized before significant heat can conduct away from the laser impact point. The laser fundamental is at 1550nm, the laser also emits at 775nm.



A good rule of thumb, coming directly from the differential equations controlling thermal diffusion in solids, is that thermal diffusion length $x(\text{cm}) = \sqrt{4 \cdot \alpha \cdot t}$ where t is the typical timescale (pulse duration here in s) and α the thermal diffusivity in cm^2/s . For metals, α is in the approximate range 0,1-1: for insulators typically 0,001.

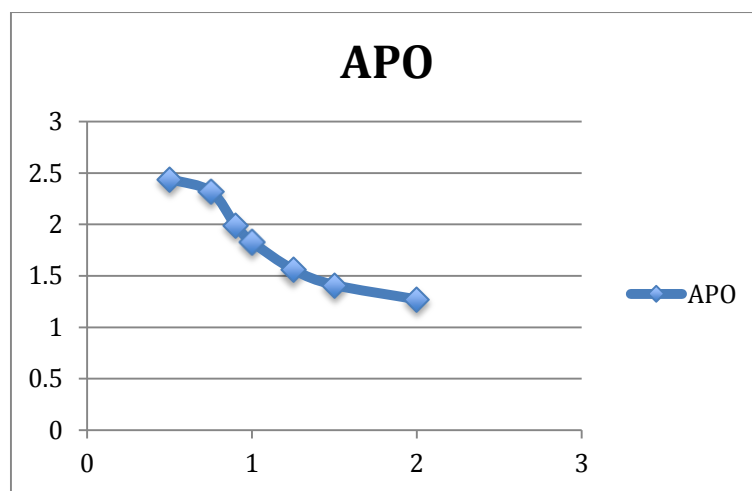
Thus for lasers with sub-ps pulse duration thermal diffusion on the timescale of pulse duration is well sub- μm and one can think of processing as being essentially non-thermal provided the beam spot is kept moving. Ps lasers have small focussed beam at high rep. rate, so scanning optics are used to move the focal point around at speeds of up to several m/s.

Energy densities are typically in the range of 1-10J/cm² at rep. rates, depending on laser source, which may exceed 1MHz; machining takes place at rates on the order of tenths of $\mu\text{m}/\text{shot}$., with typical spot sizes 1-20 μm .

1.2 Beam Spot Size

O/p beam from the laser is TEM₀₀ with $1/e^2$ dia. d . and can be expanded using a BET to dia. A . Amongst scan lens suppliers, a generally accepted ‘engineering’ formula for the focussed spot size is $d=1,21*\lambda*f.l./A$ for $1/e^2$ dia. for an untruncated TEM₀₀ Gaussian beam, about which one can immediately comment:-

- No Gaussian beam is untruncated; minor truncation gives insignificant departure from the ideal case, severe truncation leads to some complex maths. The spot is no longer truly Gaussian so the notion of $1/e^2$ points starts to suffer, but there are tables which attempt to express the resulting beam broadening as an Apodisation Factor (this is the 1,27 in the formula above, which is $APO=1,27$ for a beam diameter D_g only half the diameter of the lens pupil D_a ; for one the *same* diameter as the pupil one should use $APO=1,83$. APO values as a function of D_a/D_g are plotted (Sill Optics).



- No laser emits a perfectly Gaussian beam; the accepted measure of focussability is M^2 , which in principle is applied as a multiplicative factor to the above, and which for typical lasers can be 1.1-1.3 in the IR.
- No optics are perfect, there will always be aberrations at some level. Generally one talks of ‘diffraction limited’ meaning that level is not dominant compared to diffraction effects.
- $1/e^2$ is useful for optics theory, probably $1/e$ or half power points make more sense for materials processing, with a correction factor of $\sqrt{1/2}$ or $\sqrt{\ln 2/2}$ in those two cases, but also one finds that the minimum width of feature that can be written depends on the material, even when parameters are tweaked. One would imagine that short pulse lasers would give less material dependence on spot size, but in practice this does not seem to be the case, and processing results with various makes of ps laser bears this out.
- Practically speaking, an assumption that corrections UP for m^2 & aberrations & DOWN for half power result in a final correction factor not far from unity is probably not far from the truth.

Next point concerns the definition of A which is the effective diameter of the beam at the lens pupil. Since a beam will naturally diverge with distance, or can be expanded with a BET, one might reasonably ask if these two cases are the same, particularly since distances are relatively long in a machine like the PS450-TO. A quote from Prof. Leo Beckmann, author of the Opdesign software package, which can handle wavefronts and Gaussian beams, will help:-

« The lens does not know anything about the radiation source; it only sees in the case of a laser beam an incoming wavefront with Gaussian intensity profile and (1) with a given diameter (measured at the $1/e^2$ level) and (2) the curvature of the wavefront. More specifically, the lens does not know, what caused that curvature - just ordinary beam propagation (according to well-known formulas) or some optics (such as a telescope). The lens now modifies that curvature by its "power", which means, that it just "bends" the incoming wavefront - the only important thing a (perfect) lens really does. Thus a new wavefront emerges from the lens, which is typically made to be concave in the direction of light propagation. Together with the (unchanged!) diameter of the wavefront, such a concave wavefront is associated with a convergent Gaussian beam, the n.a. of which determines the size of the image waist. «

Prof. Beckmann goes on to point out that the exact formulae for all of these things are known, but non-linear, and therefore cannot in principle be neatly tied up in a single 'engineering' formula as above, - whilst allowing that the differences are negligible for distances less than or comparable to the Raleigh range, which are generally on the order of some meters for commercially available lasers.

The curvature of the wavefront, which does depend on upstream optics, does determine the exact axial position of the focus, though again the differences for naturally & BET expanded beams are small, and comparable to the DOF. Exact simulations using Opdesign confirm all of these points.

1.3 Unpacking

The IIT Kanpur BDU is shipped in a strong wooden case, which should be inspected on arrival; in case of any signs of external damage the recipient should contact his shipper and Optec immediately, and take photos, if possible date stamped.

In most cases, unpacking will be supervised by Optec or distributor technical staff during system installation. Full unpacking should only proceed in an appropriate clean environment; this is a delicate high precision machine. Removal of lateral panels reveals the MM fixed to the shipping pallet. One panel serves as a ramp to unload the system if no fork lift is available.

1.4 Installation

In all cases, IIT Kanpur BDU installation, including removal of the machine from the shipping pallet, is carried out by qualified Optec (or distributor) service engineers.

N.B. Attempts to install the workstation without Optec or approved distributor supervision may void the warranty.

Generally, installation is accompanied by customer training, which should be given to as many as possible of the potential system users.

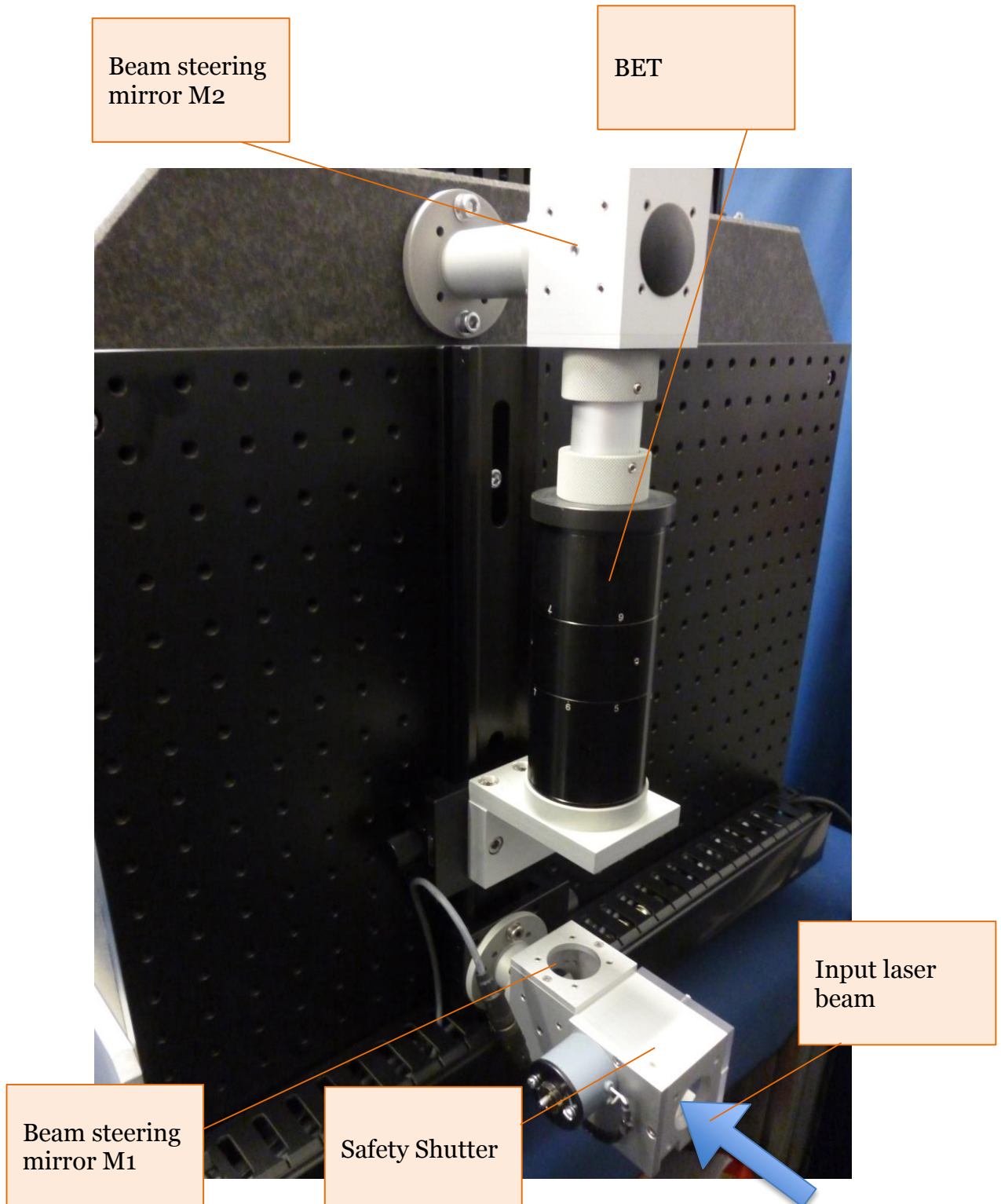
1.5 Safety

- 1) The IIT Kanpur BDU contains no laser source and therefore has to satisfy no laser safety norms. When used in conjunction with customer supplied laser it may conform to directive EN 60825 (Laser radiation) as a Class IV laser system capable of emitting laser radiation at levels harmful to health. It is the responsibility of the operator, in conjunction with the laser supplier, to ensure that suitable safety precautions are applied. Otherwise, the system conforms to the provisions of the CE directive 'Machines' 89/392/CEE modified by the directive 91/368/CEE (CE marking), Safety at Work (ARAB) Art. 54, directive 73/23/CEE (low voltage), directive 89/336/CEE (EMC), various harmonized norms EN 60204, EN 50081-2, EN 50082-2.
- 2) The system is to be used for laser micromachining. Note that ablation products, particularly of polymers, may contain toxins and carcinogens, typically as also resulting from incomplete pyrolysis of plastics, - for e.g. on an open fire. In many R&D situations, quantities are strictly minimal and of limited hazard. In production applications process fumes should be evacuated to a suitable exhaust.

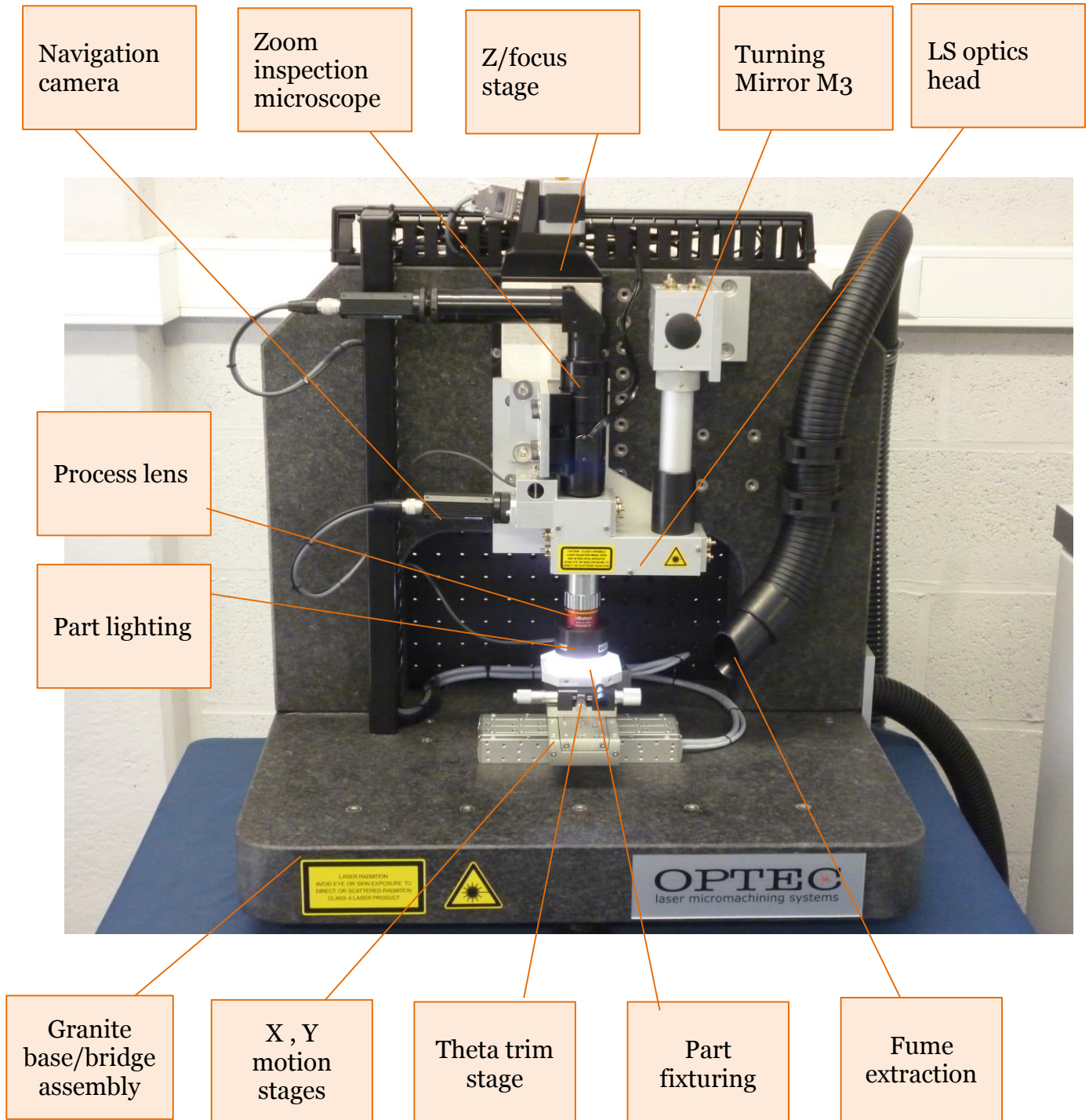
2 IIT Kanpur BDU on Detail

2.1 IIT Kanpur - Optics

Upstream Beam Delivery



LightShot BDU



For individual components the user is directed to the manufacturer's documentation, complimented by the notes below, and taken in the order of the beam path.

Laser Safety Shutter

Operated by the Optec ProcessPower software

Steering Mirror M1

Used to direct the input laser beam towards M2, and through the BET. The mirror is HR>99% @ 765-785nm + HR>98% @ 1530-1570nm AOI=45°; Low GDD.

BET

Is used to expand the beam so as to have a smaller focussed spot; see RA26 Technote attached. Also see Altechna operating instructions. Expansion ratio is 1-6X

Steering Mirror M2

Used to direct the laser beam through the granite structure. The mirror is HR>99% @ 765-785nm + HR>98% @ 1530-1570nm AOI=45°; Low GDD.

Steering Mirror M3

Used to direct the laser beam towards the LightShot LS optics head. The mirror is HR>99% @ 765-785nm + HR>98% @ 1530-1570nm AOI=45°; Low GDD.

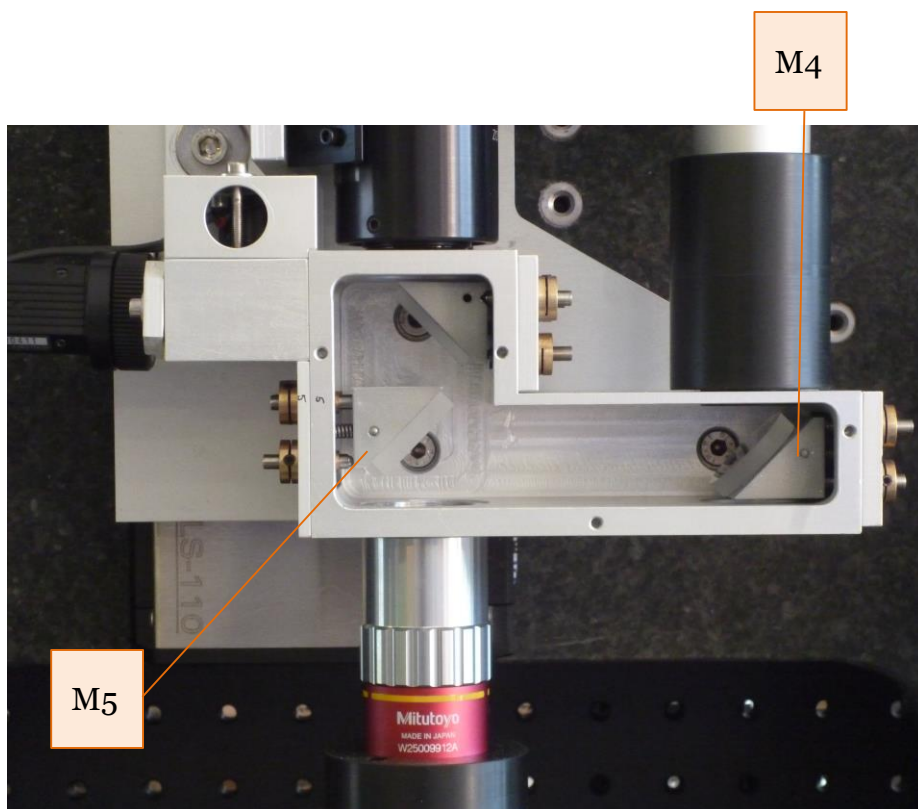
LS Optics Head

The LS optics head is used to inject the laser beam in the vision optical path.

We satisfy your curiosity into the internal content of the LS head in the picture here, better not to remove the cover.

There are NO user serviceable parts in the LS head, and the mirror settings (6X brass adjusters) must NOT be disturbed without thorough understanding of their function.

The LS head is set up to that a laser beam correctly aligned through M4 & M5 will be in the centre of the optical field of view (FOV). When setting up with a new laser, adjustments of M4 & M5 should be used to achieve this; the procedure is as follows:-



- Set up the laser so that the beam is centered on M4, and perpendicular to the plane of the back of the BDU.
- Adjust M4 to centre the beam on M5;
- Adjust M5 to centre the beam on the i/p aperture of the LS head (black tube in above picture)
- Observe beam impact point in visual field
- Trim M5 to centre beam impact point in visual field.

Process Lens

The process lens is Mitutoyo M Plan APO NIR, with 0,26 n.a., nominal f.l. 20mm, w.d. 30,5mm. Theoretical resolution is 1,1 μ m with 4,1 μ m DOF.

Vision

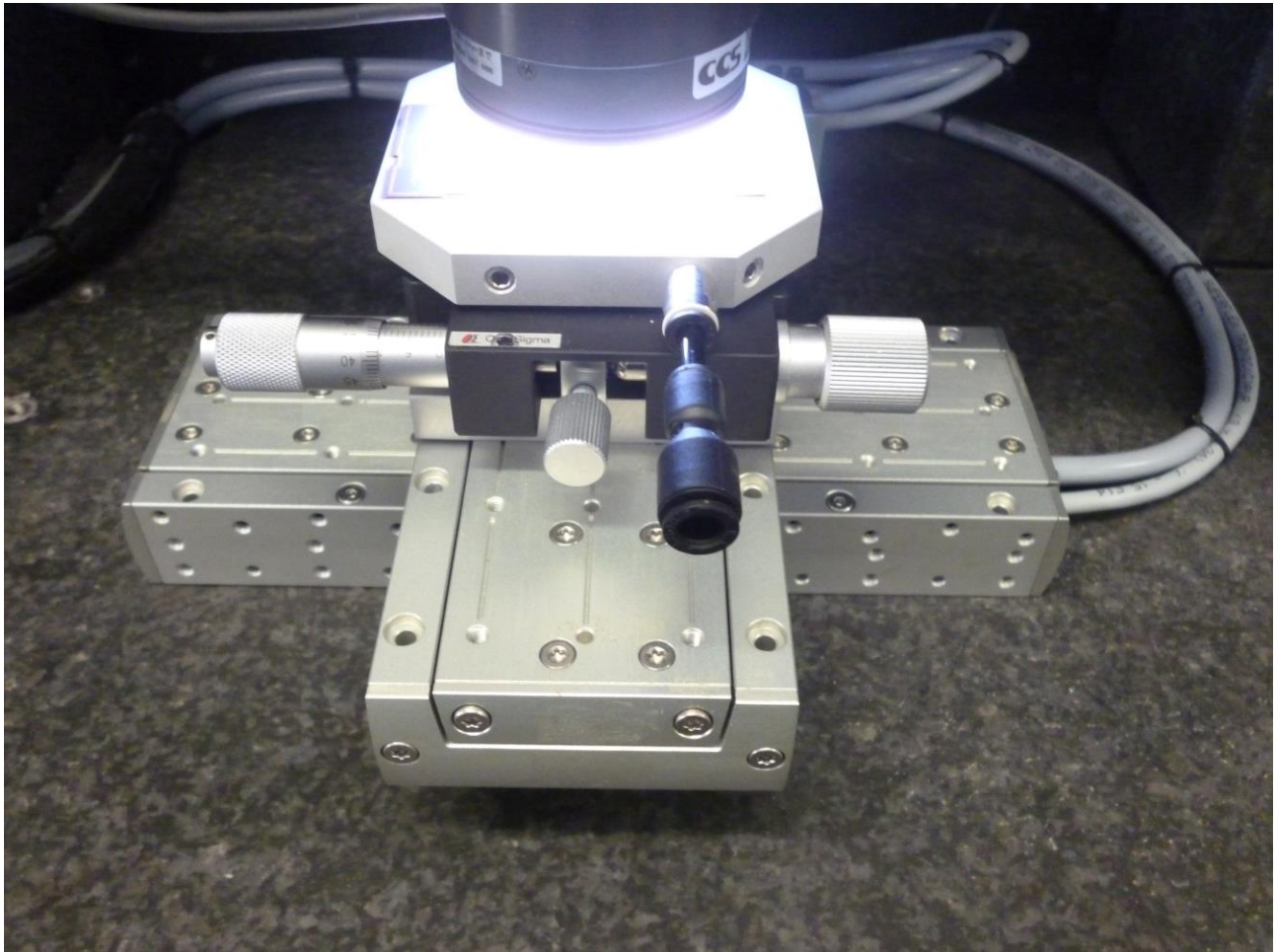
The system includes a Thales Optem 125C zoom microscope. Motorized zoom is set at discrete levels in ProcessPower software, with automatic adjustment of lighting intensity to maintain constant image brightness.

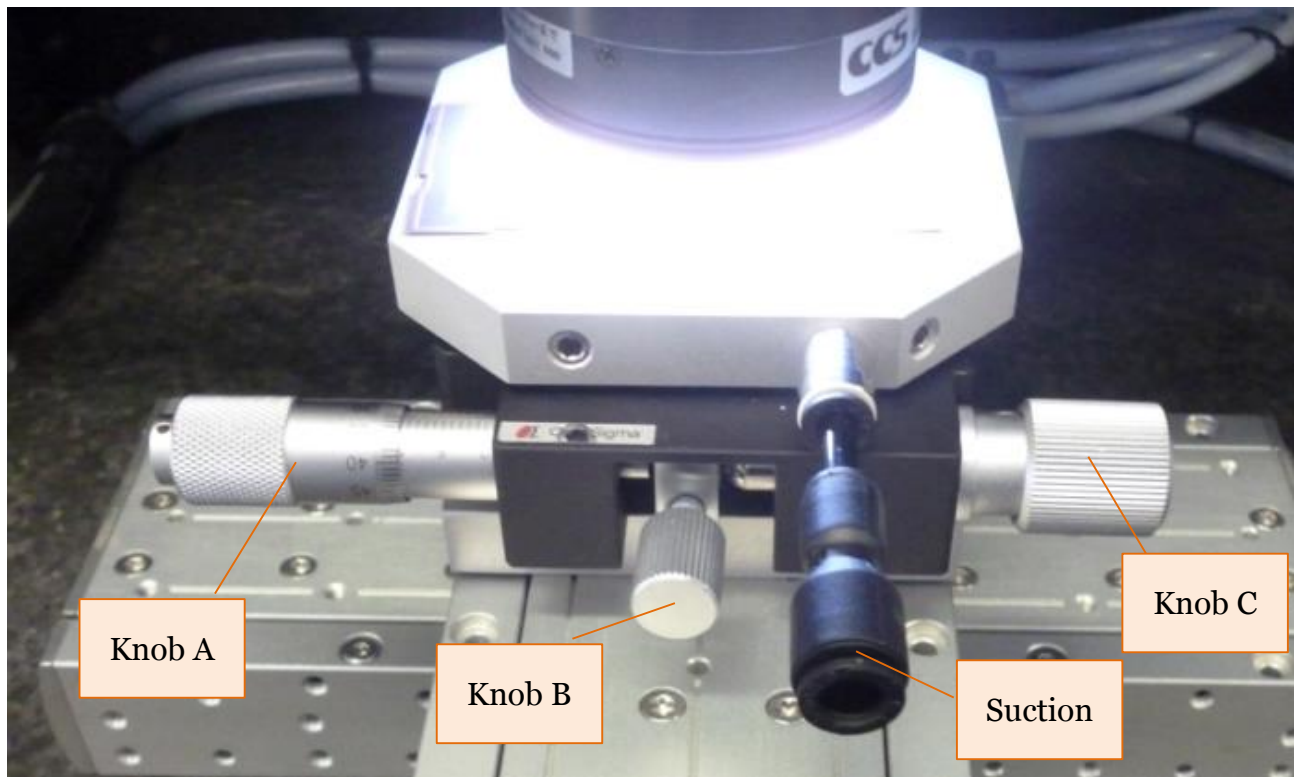
An additional area view navigation camera is provided.

2.2 Mechanics

Part Motion – XY stages

Linear motor drive stages are from Jenny Science, with 135mm travel, 1 μ m resolution. For other details refer to Jenny Science documentation and notes on Optec ProcessPower.



Part Motion – Theta Trim stage

With knob B released, the stage can be rotated freely 360°.; tighten B to lock in a position.

Use knob A to rotate precisely over approximately $\pm 5^\circ$ angular range.

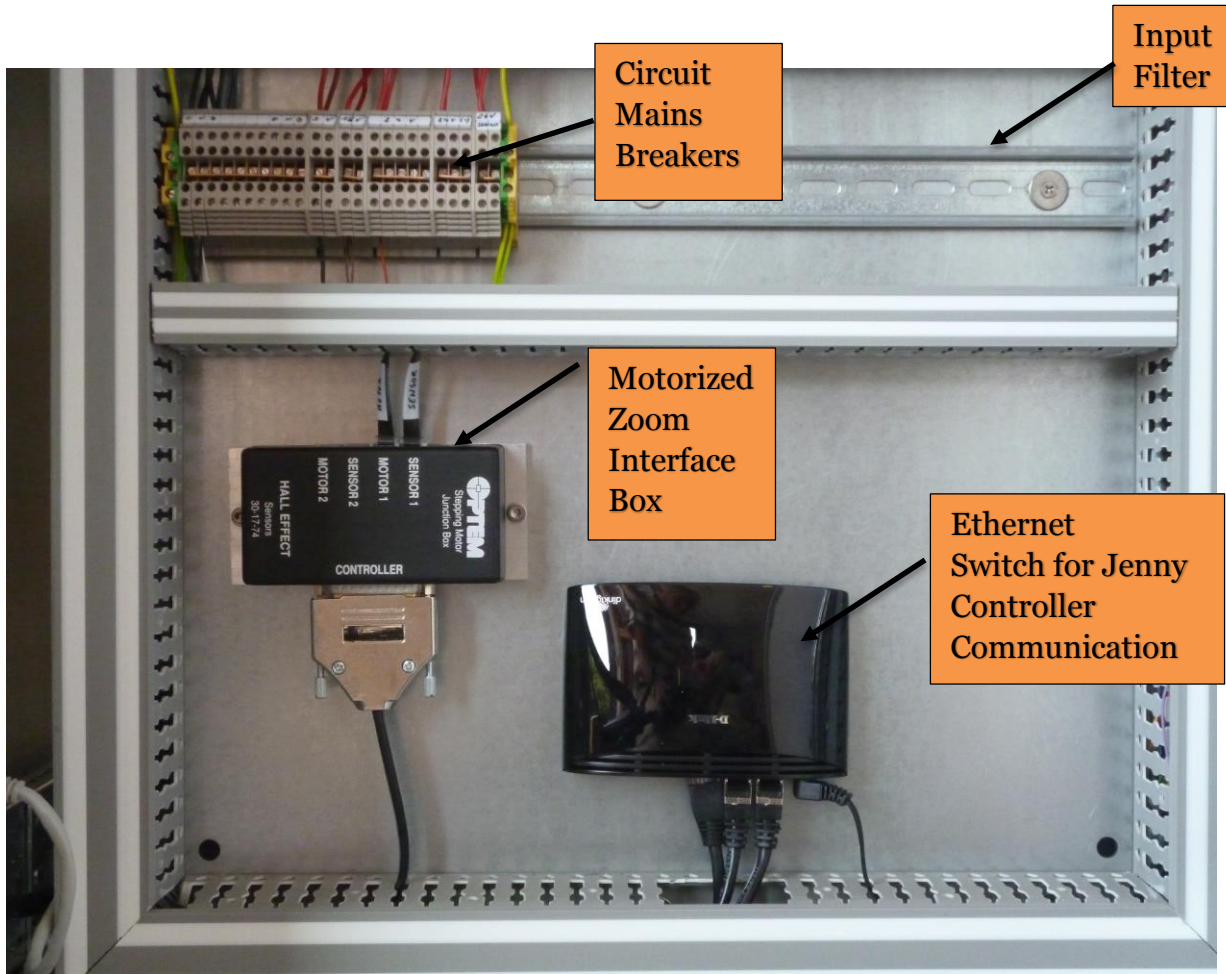
Knob A can be locked to prevent further movement by tightening knob C; light pressure is sufficient; do not overtighten.

Part Holder

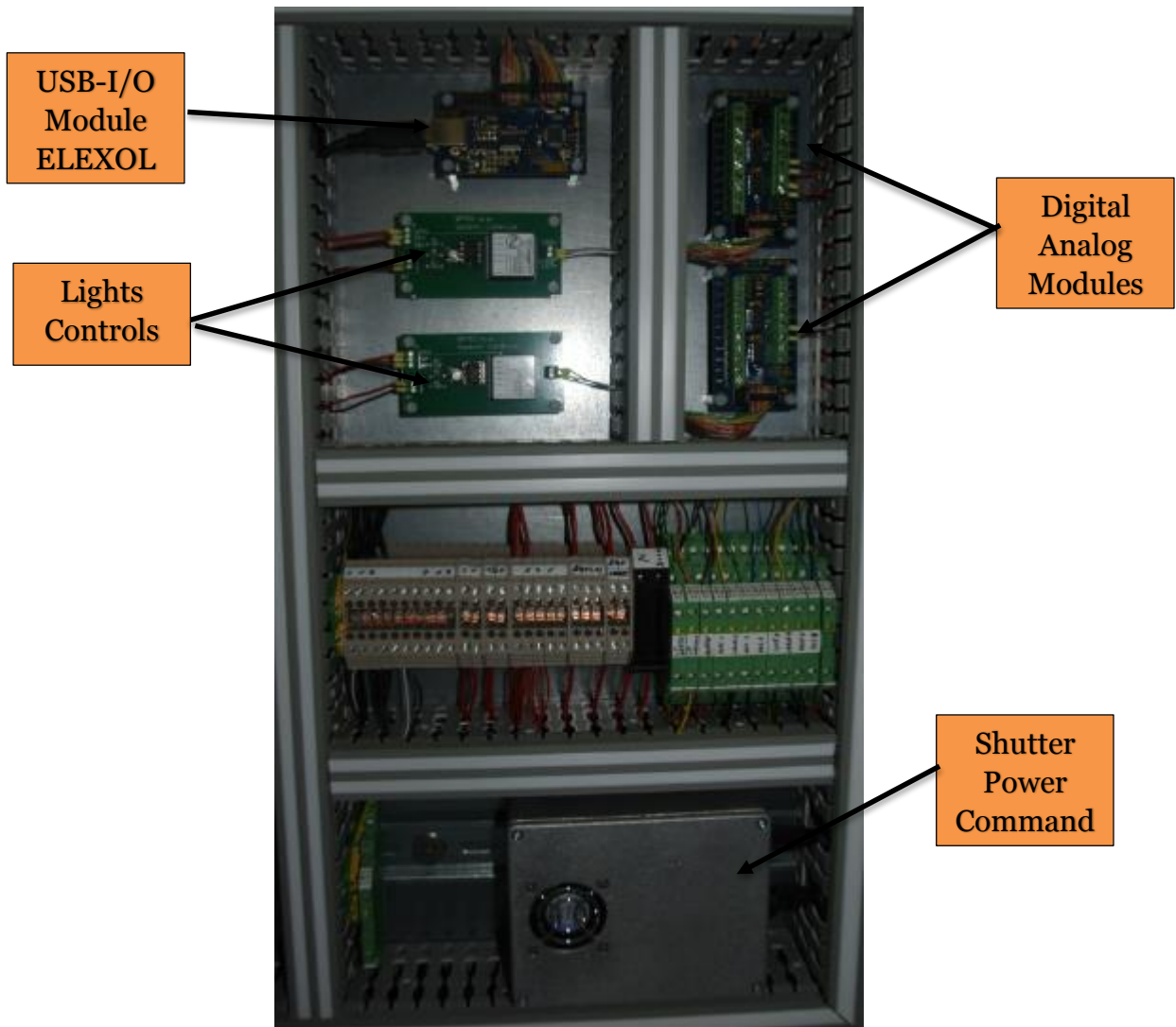
Flat parts can be held on the suction stage by connecting part vacuum to the 6mm quick fit port as shown.

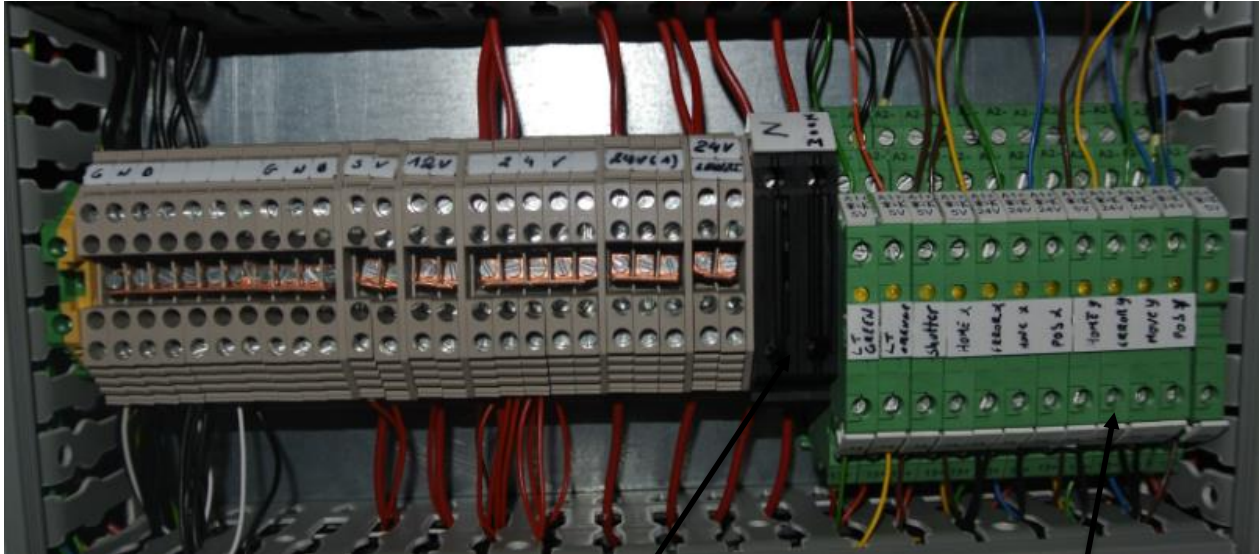
2.3 Electrics

Here are annotated pictures of the various rack of the machine.









Zoom
Power
Fuse

OptoCouplers
IN-OUT
5/24Vdc

3 USING THE SYSTEM

3.1 Starting Up/Shutting Down

Initial installation will be carried out by an Optec trained service engineer. In day-to-day operation:-

Start Up

- 1) Ensure that the service keyswitch is removed; starting in service mode affects safety.
- 2) Switch on BDU with main breakers (rack side) and keyswitch.(on control box)
- 3) Start laser software. Some lasers have a warm-up period, see the laser manual.
- 4) Start ProcessPower. If an operator code is required, default code on shipping is 10091946
- 5) Toggle between these two applications using Alt+Tab in the normal way.

Shut-Down

- 1) Quit ProcessPower, saving data as desired.
- 2) Quit the laser control program if this is operative
- 3) Quit any other active application
- 4) Quit Windows in the authorized manner to avoid possible hard disk damage.
- 5) When invited to switch off the PC, switch off the complete workstation at the front panel keyswitch.
- 6) Disconnect the workstation from the electrical supply.

3.2 Getting Started

Training will be given at the time of machine installation.

Simple Processing

With IIT-BDU systems, properly aligned and calibrated, micromachining becomes as easy as ABC:-

- A Focus the on the part using the Flex Z control, and adjust part lighting with intensity control and/or software control of camera settings.
- B When the part is in focus, the laser beam is also in focus.
- C Use the **ProcessPower** routines determine the best process parameters.

Like any complex machine, it takes time to learn to drive expertly.

N.B. Correct alignment and calibration of the IIT-BDU will repay itself many times over in ease of use.

3.3 Precautions/Maintenance

- 1) Like all precision machines, the IIT-BDU should be installed in a clean location, and kept clean. Avoid unnecessary shocks.
- 2) All users should be acquainted with the instruction manuals, and if possible have received training in IIT-BDU use.
- 3) Optics should be kept clean at all times. Dust etc. should be removed with CLEAN air blow, more stubborn particles with camel hair brush. If fall in reflectivity/transmission is observed (power meter), optics should be cleaned using reactive grade solvents, NEW optical tissues for each wipe and approved procedures. A small energy meter should be considered an indispensable part of support equipment.
- 4) Optics performance can be severely degraded by cracking of airborne organic compounds, including oils, greases, polymer processing fumes, hot transformers and the like, human body odours, city smells etc. If you can smell it, it's there. Even if you can't smell it, it's maybe still there. Best is to operate in a clean environment.
- 5) Optics alignment should be checked regularly. IIT-BDU performance and optics lifetimes are prolonged by correct operation.
- 6) Quit operating program and operating system in the authorized manner.

3.4 Optical Alignment/Setting up the System.

Principle

Systems involving many mirrors can be tricky to align, and the only workable procedure is to use an alignment laser backwards through the system, starting off by setting up this laser to be collinear with the projection lens optical axis, and working backwards from there. This is the procedure used to set the system up at the factory.

Factory alignments

The system is delivered in an aligned state, with the optics mounted so that:-

- 1 The lens mount is set up so that the optical axis of the projection lens is parallel to the 'Z' translation axis, and perpendicular to the part when positioned normally.
- 2 The optical path between M3 and the moving processing head is parallel to the Z movement axis: the laser beam always fall at the same position when Z is in upper or lower position.
- 3 The extension of the optical axis further reflected by M2/M1 remains parallel to optical rail.
- 4 Laser beam is entering in the center of M1.

These are the principal factory alignments necessary to ensure good performance of the system.

Adjusting the Navigation camera

The centre of the navigation camera image, when focussed, should coincide with the centre of the TTL-Zoom camera image when both images are focussed. If the centres do not coincide then adjustments should be made to the position of steering mirror of the navigation camera.



Adjusting Confocality

Since the microscope objective work at infinity, there is no confocality adjustment.

However, there is a difference between the visible wavelength and the laser wavelength. This means that the in focus distance is slightly different. For achieving the finest spot, one could be obliged to move the Z axis from the in focus position to reach the true focal point of the objective.

4 APPENDICES

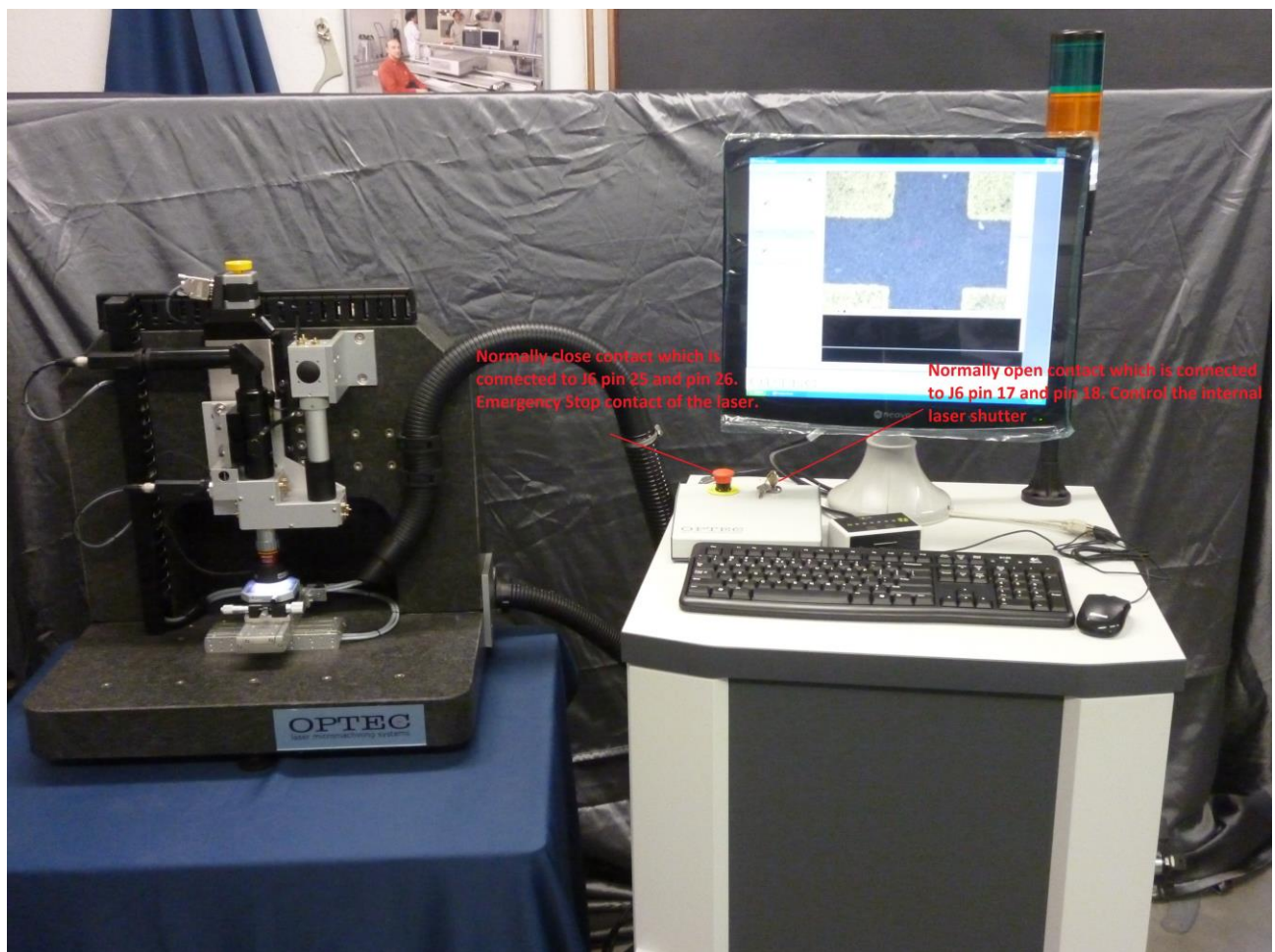
a/ ProcessPower manual

This is the general user's manual of our software. It may happens that functions described here are not available for a specific machine depending of its exact configurations.

b/ Technical documents and user's manual

Stored on an USB key

c/ Laser interface

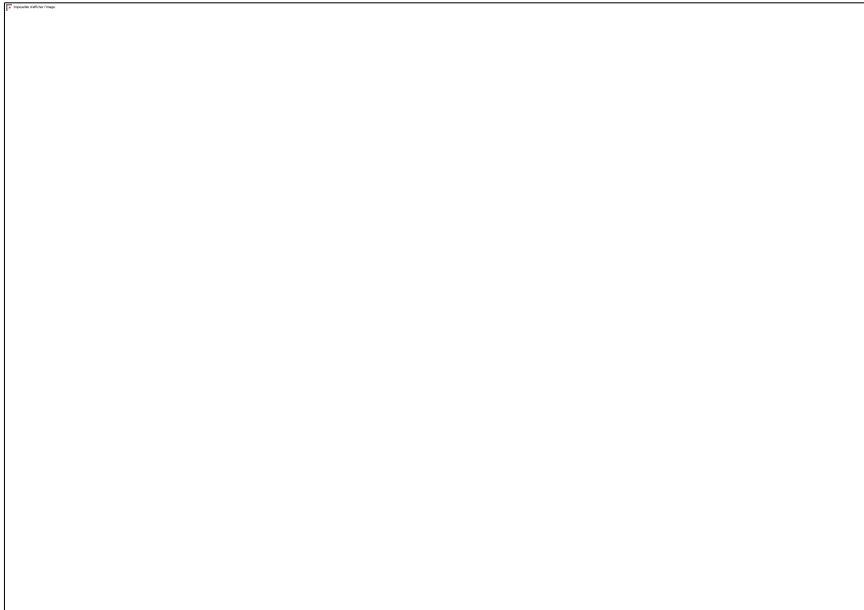


- Picture indicates where are the two dry contacts (NO and NC)

- The 0-5Vdc signal is coming from a Digital/Analog converter:

http://www.elexol.com/IO24Accessories/Analog_To_Digital_IO_Board.php

- The gating signal is coming from one output of the NStep controller from Aerotech :



It is a TTL signal OV laser off, +5Vdc Laser on.

- The Light Tower Orange is driven by the TTL signal from the laser through an optoisolator from Phoenix Contact

Model DEK-0V-5DC/24DC/3 Part number 2941361

<https://www.phoenixcontact.com/online/portal/us?uri=pxc-oc-itemdetail%3Apid=2941361&library=usen&tab=1>

5 FULL SCHEMATICS