13 Industrial engagement and component sourcing

13.1 Introduction

As discussed in Section 5, there are two principal options for HiPER. For one it is proposed to use, wherever possible, similar technology to the two large lasers currently under construction: the National Ignition Facility, NIF in the USA [10.1], and Laser Megajoule, LMJ in France [10.2]. As such the project will be making much use of the optical fabrication techniques and equipment already put in place by these facilities. This represents leverage from two multi-billion Euro scale development programmes and so offers a relatively low risk option for HiPER.

There are still areas in this design which will require significant industrial engagement over the course of the preparatory phase project to ensure a viable production route exists. Also, there is healthy competition in many areas of technology (as well as for the overall project management and civil construction aspects). Likely partners will be explored over this next phase.

In this section we highlight some of the key supply issues where specialist industry is required.

13.2 Optics

The prospect of a very large scale laser system within Europe is an excellent opportunity to engage, support and develop the technical industrial community.

The licenses for many of the processes developed for the NIF and LMJ lasers are owned by the DoE and/or CEA including that for the 46 x 81 x 4.1 cm Nd:glass laser discs. In informal discussions during the 2-year design phase, both parties expressed a willingness to permit the processes to be used by the HiPER project in conjunction with the relevant manufacturers. Using the NIF/LMJ designs reduces the risk of finding and facilitating suppliers in a lot of the key optics and associated assemblies. There are however a relatively small number of key optics which should be reviewed.

Figure 13.1 : Nd:doped phosphate laser glass coming off the production line of the continuous melt process developed for the NIF and LMJ laser systems.

With an initial estimated requirement of 1300 laser discs the most obvious issue for HiPER is the availability of sufficient laser glass since the continuous melt production lines[10.3] for NIF and LMJ will have been shut for several years before construction could begin. The HiPER project will need to explore options including mothballing; starting up production again with the two previous glass suppliers Hoya [10.4] and Schott [10.5]; and seeking other potential sources such as Shanghai Institute of fine Opto-Mechanics (SIOM) [10.6] in China, or options in Russia.

The HiPER project is likely to have a frequency conversion and focusing system based on the successfully commissioned LMJ prototype LIL [10.7]. It comprises a 1ω grating, two Potassium Di-Hydrogen Phosphate (KDP) crystals for second and third harmonic (3ω) generation, and a 3ω focusing grating. These optics specifically developed for LIL/LMJ are currently only manufactured by Jobin Yvon [10.8]. Alternative sources could be LLNL [10.9], Plymouth Grating Laboratory [10.10], Carl Zeiss [10.11] or General Atomics [10.12].

Harmonic conversion crystals and Pockels cell crystals do not appear to be critical items at this time as current designs perform reliably on NIF and LMJ. Large aperture Plasma Electrode Pockels Cells (PEPC) [10.13] required for the switching and the isolation from back reflections of the main amplifier are used in NIF, LIL as well as in Omega-EP [10.14] at the University of Rochester. The performance of these is thoroughly characterised. Large aperture Faraday isolators are proposed and being evaluated for the FIREX [10.15] laser system at the ILE in Japan (1.25 meter clear aperture) and might be another route to provide fail-safe protection from target retro-reflections for HiPER.

The final wavelength of the laser will be ultimately determined by the specific requirements of the plasma physics of the fusion interaction. The issues of the final wavelength for the compression pulse will be determined by the absorption properties of the target balloon. This is determined by the product of intensity and the square of the wavelength, $I\lambda^2$, which should be minimized. This suggests the use of the third harmonic of this type of laser (λ=351nm). However, third harmonic brings with it a significant decrease in the laser damage threshold of all subsequent optics and so work will be performed to assess the viability of operating at the second harmonic.

13.3 Components not developed for the NIF and LMJ systems

Although for the baseline design the HiPER system will be similar to the NIF and LMJ lasers for over 90% of the components, the remaining 10% hold the greatest challenge. Even so it should be possible to draw upon the experiences of other sectors of the European scientific spectrum to reduce the risk to the project.

Ignitor beam focusing: A single optic for the focusing of 24 off 400 mm by 400 mm beams is impractical due to cost, delivery timescales, and damage issues. Developments over the last few years in the large telescope community have seen extremely large telescopes (> 10 m diameter) constructed from multiple segments. These include KECK and Gran Telescopio Canarias (GTC) telescopes [10.16, 10.17]. The HiPER project has already engaged SAGEM SA [10.18] who is the manufacturer of the primary reflector for the GTC. The GTC has an f/1 primary mirror with a segment to segment alignment accuracy of +/- 5nm [10.19]. This technology will need to be fully harnessed to handle the high energy side of laser work to fulfil the requirements of the HiPER project, not an issue relevant to the telescope community.

Alternative options also exist (for example OpTIC-Technium in the UK), coupled to the growth of the optical telescope community's demands. To ensure close collaboration in this area, a Memorandum of Understanding (MoU) has been signed between HiPER and the European-Extremely Large Telescope (E-ELT) project (along with the ELI laser project).

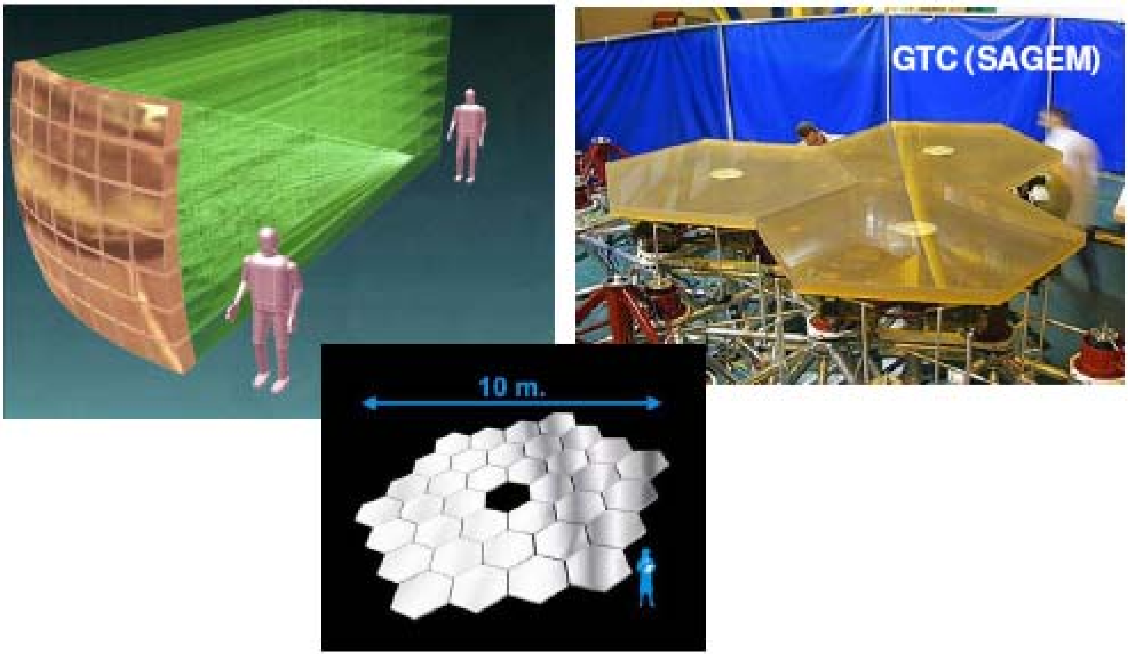

Figure 13.2: a) schematic of the multi-segment focusing optic for HiPER. b) Mirror segments undergoing final polishing at SAGEM REOSC for the GTC telescope. c) Overall size of the primary mirror on the GTC Telescope made up of 36 segments.

Ignitor beam frequency conversion: Requirements for the optimum wavelength of the short-pulse ignition beam are less well defined at present and will be determined by the experimental campaigns in the forthcoming months. The most promising option seems to be the second harmonic wavelength, 527 nm. The issue then arises as to which wavelength the pulse compression occurs at i.e. will HiPER frequency convert prior to compression or compress the pulse prior to frequency conversion. The first option would require significant effort to develop gratings with sufficiently high laser damage threshold at 527 nm. The second option would use previously developed pulse compression grating technology but would require only few mm thick Potassium Di-hydrogen Phosphate (KDP) frequency doubling crystals having sufficiently good transmitted wavefront quality. With the very high intensities involved in the short pulse these KDP crystals would be highly likely to damage and would also produce significant beam break up, affecting the quality of the focal spot achieved.

Dielectric gratings of sufficient size have been extremely difficult to obtain in previous years but the investment in large aperture lasers, specifically FIREX and OMEGA EP has resulted in a considerably increased capability. There are potentially three major suppliers of gratings with the capability to supply gratings of the appropriate specifications for HiPER: LLNL, Plymouth Grating Laboratories, and Jobin-Yvon. Progress in the past few years in production of gratings for the Omega EP laser at the University of Rochester and the FIREX laser at the University of Osaka has resulted in increased confidence that these components will not be a major source of concern in the timeframe of HiPER construction.

13.4 Technical Industrial Engagement

The HiPER project has engaged with suppliers in wider industrial fields linked to the project including suppliers of high power diode stacks, manufacturers of optical production equipment, high voltage equipment suppliers for capacitor banks, solid state laser manufacturers, Pockels cell driver unit manufacturers and flashlamp suppliers. A summary of current contacts for technical components is provided in the table below. Other links (e.g. to project management, civil design and construction, etc) are not reproduced here.

Industrial partner	***Previous expertise***	***Potential supplier of:***
AMTRON GmbH	*LULI and Max Born Institute*	*Control and supply systems of high power laser diodes*
Société Européenne de Systèmes Optiques (SESO)	*Partnered with CEA on LMJ. Worked with LLNL. LULI, Osaka, RAL*	*High damage threshold optics,* *Direct off-axis manufacturing of mirrors,* *Serial production of large optics (lenses or plates);*
DILAS	*12 years experience in High Power Diode lasers*	*High Power Diode lasers – selecting, qualifying, testing*
Hamamatsu Photonics KK	*All major laser labs*	*Precision electronic and opto-electronic devices*
Gooch and Housego PLC	*Suppliers to NIF and LMJ*	*KDP and Quartz waveplates. General optics coated to withstand high laser fluences*
CVI Technical Optics Ltd	*All major laser labs*	*Fully customised complex optical components. Design and supply opto mechanical sub assemblies*
Heraeus Noblelight Ltd	*30 years experience in arc and flash lamp manufacture*	*Flash lamps*
Kentech Instruments Ltd	*All major laser labs*	*Pockel cell drivers. X-ray streak cameras, waveform generators for laser pulse shaping*
Cleveland Crystals Inc	*Supplier to NIF and LMF, LIL projects*	*KDP and KD*P crystals. Plasma electrode pockel cell crystals*
Corning Inc	*Involved in PHELIX, LMJ, LIL, NIF*	*Synthetic Fused Silica blankets*
Glassman Europe Limited	*All major laser labs*	*High voltage DC power supplies, HV dividers for accurate measurement*
Saint-Gobain Ceramics	*LMJ, LULI, GSI*	*Flash lamps*
Plymouth Grating Laboratory	*ILE, LLE*	*Gratings and Diffractive Optics*
SAGEM - REOSC	*LMJ*	*Refining the specification of optical components (mirrors, parabola, lenses*
HOYA	*LMJ, NIF*	*Laser glass*

Horiba Jobin Yvon	*All major laser labs*	*Large aperture dielectric gratings*
Tinsley	*25 years experience and supplier to NIF, Omega, LMJ*	*Optical finishing processes*
Thales	*All major laser labs*	*Solid state lasers, power and nanosecond pump lasers*
JENOPTIK Laser	*IST, MPQ, Jena*	*Diode laser pump modules and pump optics. Optics for beam line configurations*
OpTIC	*Telescope Industry*	*Optronics technologies, capability in large optical surfaces and laser equipment*

Table 13.1: List of technical companies approached in support of the HiPER project.

13.5 Conclusion

The HiPER project can reduce the risk associated with designing a laser system from the ground up by basing the system design on the NIF and LMJ designs. By engaging supply companies at an early stage issues associated with NIF and LMJ standard optics can be readily resolved. It is essential the HiPER project adapts as much as it can from other branches of science for the Ignition beamlines.

The prior 2-year design phase has already established key industrial contacts in the technical and project delivery areas. This preparatory phase will see the formalisation of these links to ensure low-risk passage to the subsequent construction phase.

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