Researchers at the Institute of Photonics, University of Strathclyde, have started work on a 3.5 year project to develop a novel solid-state laser design incorporating CVD (chemical vapour deposition) diamond manufactured by Element Six Ltd. Element Six leads the world in the field of CVD diamond synthesis and its application.

The development of a diamond Raman laser could open up a raft of new application areas in, for example, underwater imaging, medical imaging, ophthalmology, cancer therapy and multispectral imaging. The project will be led by Dr. Alan Kemp at the Institute of Photonics, University of Strathclyde supported by a grant of more than £600,000 from the UK government-funded Engineering and Physical Sciences Research Council, EPSRC.

The use of diamond as a solid-state laser material opens up new opportunities to design small, compact solid state lasers with greater power handling capabilities and operating at currently unavailable wavelengths so opening up new application areas. Diamond has a unique combination of optical and thermal properties that make it suitable for this application and these properties can be exploited through the latest single crystal CVD material produced by Element Six. Raman lasers have already been developed using materials such as silicon, for example, and are used in telecommunications, but the use of diamond could move their capabilities to new power levels and wavelengths.

How Raman lasers work

Raman lasers make use of a phenomenon called Raman Scattering discovered in 1922. When photons hit a substance, a tiny fraction of them interact by causing the atoms of the substance to vibrate. In such ‘inelastic’ collisions, the photons gain or lose specific amounts of energy, resulting in light of a different wavelength. A Raman laser amplifies the secondary light by oscillating it and pumping energy into the system to emit a coherent laser beam.

The importance of this type of laser is that it can shift the wavelength. As Dr. Kemp says the ability to shift the wavelengths “gives access to the applications-rich, but currently source-poor, yellow-orange region of the spectrum.” Today, most commercial lasers operate in the near infrared region of the spectrum between 0.8 µm to 1.1 µm with a particular concentration around 1 µm (1.03 – 1.07 µm) where most of the high performance laser work is done. “Perhaps the most important challenge in modern solid-state laser engineering,” says Dr. Kemp, “is to find ways to generate new wavelengths but in doing so to retain as much as possible of the convenience and performance of current lasers.”

Potential of synthetic diamond

In addition, current generations of continuous wave solid state Raman lasers have been limited to powers of only a few watts due to thermal problems.

Fig 1: Low Birefringence diamond

Diamond has excellent thermal conductivity combined with a low thermal coefficient of expansion allowing greater power handling capability. “The least glamorous but most pervasive problem in laser engineering, particularly when you want high performance in a small package, is how to deal with heat,” points out Dr. Kemp. “This is particularly problematic in high power Raman lasers because crystals that are good Raman converters are typically rather poor conductors of heat. This is where diamond comes in. With a thermal conductivity that is two to three orders of magnitude better than typical Raman active crystals, it should be an excellent Raman medium and allow us to generate much higher output powers.” In addition, diamond shifts the wavelength slightly further than the Raman-active crystals that are currently used which may extend its application potential. “The team at the Institute of Physics has recognised that diamond has a high Raman gain coefficient and a large Raman shift compared to conventional Raman media,” adds Chris Wort, Technical Manager at Element Six.

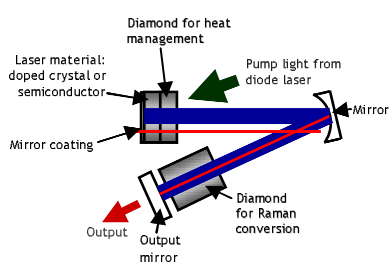

Fig. 2: Possible layout for a continuous-wave intracavity Raman laser using diamond.
The cavity mirrors reflect both the fundamental laser wavelength (e.g 1064nm, blue in the diagram) and the Raman generated Stokes wavelength (e.g. 1240nm, red in the diagram) – the output mirror is partially transmitting at the Stokes wavelength to extract the power at this wavelength.

(diagram courtesy Institute of Photonics)

A vital property of the diamond supplied by Element Six is that it exhibits ultra-low birefringence. Birefringence is when the speed of light in a medium varies if the polarisation of the light changes and this has to be carefully controlled in a laser cavity in order to make the laser work well. Dr. Kemp says, “The ultra-low birefringence single crystal CVD diamond that E6 produces is a real step forward for all photonics applications of diamond, particularly laser applications. It allows us to exploit the exceptional properties of diamond without compromising other aspects of the laser’s performance.”

Element Six is to supply the research team with high quality single crystal CVD diamond for the duration of the project. The Institute of Photonics has a good working relationship with Element Six. The organisations have previously worked together on the government supported MIDDI project under which has led to the ability to carry out precision etching of single crystal diamond micro-optics, for example.

About the Institute of Photonics

The Institute of Photonics, established in 1995, is a commercially-oriented research unit, part of the University of Strathclyde. Its key objective is to bridge the gap between academic research and industrial applications and development in the area of photonics. The Institute’s research interests include semiconductor materials and devices, practical, all solid state lasers, micro-LED arrays and a wide range of applications particularly in biophotonics. The Institute of Photonics is based in Strathclyde’s Glasgow city centre campus. The IoP undertakes contract and collaborative research with industry and offers consultancy. It has a large number of PhD and EngD students, and licences technologies to companies.