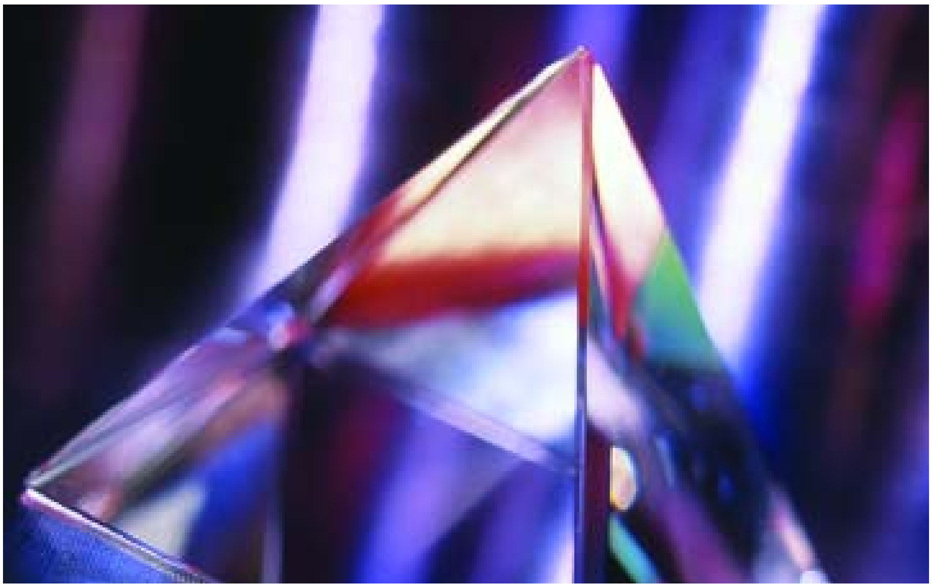
Engineers have a wealth of choice on their hands when it comes to selecting a laser. Similarly, manufacturers have a choice when selecting components for their finished products. Here, **Warren Clark** looks at one such core component, the laser crystal



A clear choice of crystals

JUST AS A LASER SYSTEM MIGHT END UP being a component of a much larger set-up in an application, so the crystal is a part of some types of laser system itself – albeit a key part. But what do manufacturers look for in a crystal and what types of crystal are available?

Tony Vere, CEO of The Crystal Consortium, a company that works with customers to create bespoke crystals, such as those for lasers, says: 'One of the problems of specifying any component, and particularly when it's crystals for lasers, is that what you leave out is usually, with the benefit of hindsight, more important than what you put in.'

A laser crystal can be engineered according to the needs of the laser system for which it is intended. Scott E. Griffin is director of sales and marketing at Northrop Grumman Synoptics, a company that produces crystals for lasers. 'There are many different properties of a laser crystal that can impact the performance of the laser system being produced,' says Griffin. 'Each laser system has its own unique output parameters, which means the laser crystal will vary in terms of specifications from manufacturer to manufacturer. For example, for Nd:YAG, which is the most widely used laser crystal today, we have more than 6,000 unique part numbers for this one material. Each item produced is truly a custom job.

'Parameters will vary from required Nd concentration, wavefront distortion, end configuration, coating design, etc. It is critical for us to have a strong relationship and good open communication with all of our customers to ensure that the product being produced will provide the desired output in the laser.'

'The two most important parameters are clearly the wavelength at which you want to operate and the power output you need to achieve,' says The Crystal Consortium's Tony Vere. 'Surprisingly, the first is relatively easy – there is ample literature on lasing transitions and the dopants and host-lattices (the basic crystal) required to achieve them. Power output, too, is not a problem at levels up to a few watts but, beyond that, you need to begin to consider the optical damage threshold. Unfortunately, this is a very imprecise parameter, dependent on a multiplicity of interrelated properties of the crystal, the pump mode and method of crystal mounting – not to mention the mechanical and thermal properties of the material itself and the presence or absence of defects either on the surface or in the bulk. If high power output is the aim, then I agree with Scott: you need a very close relationship with your crystal grower. It also helps to take advice from an independent R&D laboratory, or vendors who source crystals from around the globe.

'Specifications aimed at high power levels need to be more wide-ranging – sometimes it is important to stipulate the crystallographic direction you require for the axis of the laser rod. Laser crystals sometimes contain a central core and edge facets, where the concentration of the dopant can change significantly, so in some cases it is even necessary to specify the part of the crystal from which the rod should be cut. Optical transmission and absorption data will also help to establish that the crystal has the required properties. Even straightforward parameters, such as the tolerances on crystal dimensions and orientation, are worth specifying – though frequently omitted.

'A final word of advice applies to slab lasers and non-linear optical crystals – it's well worth specifying an inspection polish of the side faces of the component. Laser jocks tend to get preoccupied with overspecifying the much higher optical quality finish required on the beam entrance and exit faces. A quick microsopic examination of the face parallel to the beam propagation direction can frequently reveal much more about the quality of the crystal.'

The specifications of the crystal are important, of course, but then so is appropriate advice and support. Your choice of supplier can be as important as your choice of crystal.

'Manufacturers of solid-state laser systems look for a source that offers crystals of a high quality, on a consistent and reliable basis,' says Griffin. 'Pricing is, of course, an important factor in choosing a supplier, but purchasing solely on price can prove to be disastrous if the company does not have the infrastructure and capacity in place to meet its customers requirements in terms of quality and delivery.'

Brian Henderson, product sales manager for Roditi International (a distributor for Saint-Gobain Laser Crystals) agrees: 'I cannot stress enough the need for more cooperation and understanding between the crystal supplier and laser manufacturer. There have been times when customers have ended up simply throwing money away, only because they were looking to save a few pennies on the price of a laser rod – itself the key to the whole operation.

'Unfortunately, in today's market, the crystal is treated by many customers as being a simple commodity, and prices have been forced down to such a level that reinvestment in crystal materials is very low. However, nobody knows as much about the crystal as the grower. A good buyer will recognise the desire to work with the crystal grower and, together, both parties will be successful. Too often, when there is a problem with the laser, the first thing on the list to be condemned is the crystal – but it is often due to the fact that another component in the laser has been changed, but totally ignored as being the problem. This can, and does, end up with a huge loss of time and expense.'

Griffin adds: 'At Synoptics, investments in all areas of manufacturing have allowed us to meet all demands in terms of reliable delivery and stringent passive specifications of the crystals being produced. All areas of manufacture take place within one facility – from crystal growth, to rough fabrication, to polishing, to thin film deposition. We maintain full control of these processes, which ensures the highest possibly quality.'

As with any technology, of course, there are different laser crystals for different markets. This is reflected in the four markets targeted by Synoptics – military, industrial, medical and scientific.

Crystal options

Nd:YAG

Neodymium-doped yttrium aluminium garnet laser crystal (Nd: YAG) is a popular choice for systems designers, largely because of its versatility. Suitable applications include materials processing, welding, cutting, medical laser systems, pulse and CW operation and slab technology.

Ruby

Ruby is a popular choice for providing intense, high-power pulses of visible spectrum energy. It combines excellent physical and optical properties with good laser performance characteristics. Applications include: high-power Q-switched system, capable of creating the energy densities needed to generate Thomson scattering in plasma diagnostics; high-brightness holographic camera systems with long coherent length; laser metal working systems capable of drilling holes in hard materials; and medical systems used for cosmetic dermatology and tattoo removal.

Cr4:YAG Passive Q-Switch Crystals

Cr4+:YAG crystals have several advantages compared to traditional passive Q-switching choices, such as organic dyes and colour centres materials. Crystal passive Q-switch is preferred for simplicity of manufacturing and operation, low cost, and reduced system size and weight. Cr4+:YAG is chemically stable, UV resistant and it is durable. Cr4+:YAG will operate over a wide range of temperatures and conditions. The good thermal conductivity of Cr4+:YAG is well suited for high average power applications.

CTH:YAG

Chromium, thulium, holmium-doped: yttrium aluminium garnet laser crystals (CTH:YAG), provide lasing at 2.13μm, and are finding more and more applications, especially in the medical industry. The inherent advantage of the crystal is that it employs YAG as the host. Lasers operating at 2.13μm couple well into water and body fluids, and can take advantage of using silica fibres for easy, accurate beam delivery.

Er:YAG

Lasers powered by Er:YAG (erbium substituted: yttrium aluminium garnet),

operating at 2.94µm, also couple well into water and body fluids. This is especially useful for applications in the fields of laser medicine and dentistry. The output of Er:YAG enables the painless monitoring of blood sugar levels, while safely reducing the risk of infection. It is also effective for laser treatment of soft tissue, such as cosmetic resurfacing. It is equally useful for treating hard tissue such as tooth enamel.

Yb:YAG

Ytterbium-doped: yttrium aluminium garnet laser crystals are emerging as a high-power laser material. Several applications are being developed in the field of industrial lasers, such as metal cutting and welding. With a wide pump band and excellent emission cross-section, Yb:YAG is an ideal crystal for diode pumping.

Ti:sapphire

Titanium-doped: sapphire is an optically pumped, solid-state laser material with an indefinitely long stability and useful life. It is the most widely used crystal for wavelength tunable lasers and it is a leading material in the field of femtosecond pulse lasers. Ti:sapphire laser crystals combine the excellent thermal, physical and optical properties of sapphire with the broadest tunable range of any known material. Laser output can be can be generated over the entire spectrum from 650nm to 1100nm. Frequency doubling the output provides tunability across the blue-green region of the visible spectrum.

Information supplied by Roditi International and Saint-Gobain Crystals and Detectors.

'We offer a diverse range of crystals across the wavelength spectrum of 532nm through 3000nm,' continues Griffin. 'However, we do not manufacture each and every crystal that may operate across these wavelengths. We have made a strategic decision to offer materials that offer a critical importance and need within these key markets, and that assures we can maintain the necessary focus in meeting the requirements of our customer base. We also work very closely with our customer base in the development of new laser crystals that will meet the needs of next-generation laser systems. This is done through externally-funded contract crystal growth orders and also through internal research and development.'

It's important to know the limits of your own knowledge when it comes to buying crystals, as an ill-informed decision can lead to a waste of time and money – as well as a laser that does not function, of course.

'I divide crystal buyers into three categories: expert, intelligent and ordinary,' says Vere. 'The expert knows as much about the crystal as the grower and wants a very close relationship. He probably builds laser systems and doesn't read articles on how to source crystals. Many of The Crystal Consortium's customers fall into this category and we work with them on joint crystal development programmes. The intelligent buyer is less well informed, but has combed the relevant websites and literature and knows what he wants and the questions to ask. He uses laser systems and has encountered some of the crystal problems. The ordinary buyer doesn't read articles on sourcing crystals either – so long as his laser works when he turns it on, he's happy – when it doesn't, he buys another!'

Of course, the laser crystal works alongside many other components to create the final laser system, such as optics, flash-lamps, diodes, cooling system, electronics and so on. But, if you start with a correctly-specified laser crystal, you are well on the way to creating a laser system ideal for your needs.