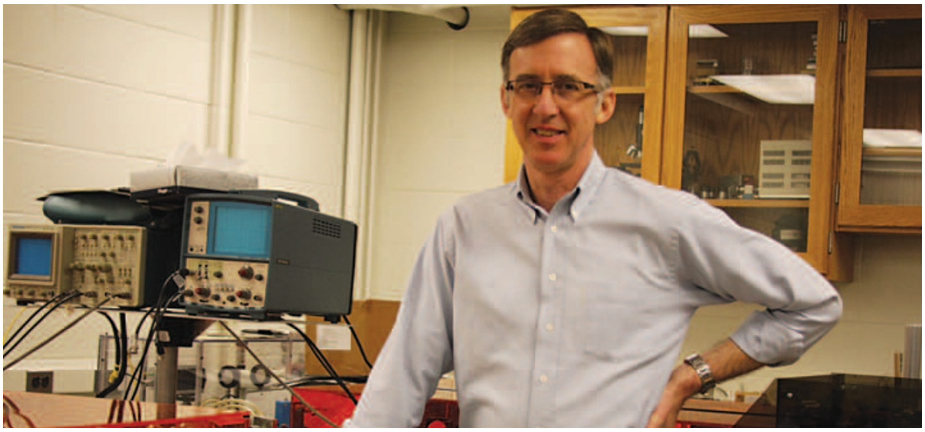
Crystal clear

A semiconductor is usually opaque to any light whose photon energy is larger than the semiconductor bandgap. *Nature Photonics* spoke to Stephen Durbin about how to render GaAs semiconductor crystals transparent using intense X-ray pulses.



YING LARIMORE

Stephen Durbin and colleagues have used X-rays to make GaAs transparent to light that would ordinarily be strongly absorbed.

What did you do in your study?

Scientists usually pump a sample with a laser and then use X-rays to see what's happening inside. Instead, we used an intense X-ray source with a lot of energy per pulse to modify the material rays and then probe its characteristics with laser pulses. Our work was inspired by a reflectivity study on GaAs that used a free-electron laser (FEL) — the FLASH facility in Germany — at a much lower energy of around 100 eV, which is not really the X-ray regime. This earlier work was a non-resonant study, meaning that they weren't probing the bandgap. We realized that we could use this approach to probe the impact of X-rays on the semiconductor and investigate the characteristic feature of a semiconductor — its bandgap.

We exposed a thin crystal of GaAs to a very intense X-ray pulse. Near-visible light, at a wavelength a little above the bandgap of GaAs, is usually strongly absorbed. However, the sample became transparent to light immediately after the X-rays had deposited their energy — a demonstration of X-ray-induced optical transmission. This is not some small effect that you need to dig out from the noise; the amount of light transmitted increased about forty times over a few picoseconds. We used 60-μm-thick samples because the $1/e$ absorption length of our X-rays was around 30 μm. When we used light at wavelengths just below the GaAs bandgap, which would normally be transmitted, the opposite effect was observed — X-ray-induced optical absorption. Although we have some ideas as to the origins of this effect, we are far from certain. The experiments must be continued, at the Linac Coherent Light Source (LCLS) at Stanford in the USA, for example, and there are a significant number of many-body physics and semiconductor bandgap problems remaining to be solved. We hope that our results will attract the attention of theorists from around the globe.

What is special about your X-ray source?

One of the beamlines at the Advanced Photon Source at the Argonne National Laboratory was originally designed for the time-resolved crystallography of proteins, in which the protein is hit with a powerful laser pulse followed by X-ray pulses. The special feature of this beamline is a shutter that allows the time between X-ray pulses to be adjusted. The pulses are usually nanoseconds apart, but this pulse spacing control allowed us to look at the evolution over longer time periods, up to a tenth of a millisecond. Of course we are also interested in the picosecond regime, but this special shutter was the key enabler in the demonstration of X-ray-induced optical transmission.

How could this transparency prove useful?

Our scheme is not yet suitable for use in a commercial device, but we are close to producing a diagnostic and detection tool for FEL sources that will allow the accurate determination of the timing between the pulses. Also, increasing the sensitivity of the scheme to avoid the use of intense X-ray pulses, for example through focusing techniques, could allow the realization of miniature X-ray-induced optical transmission devices. Optical fibres could bring light in and out of a small volume, and the absorption and transmission of this volume could be controlled by electronic excitations caused by X-rays.

What are your thoughts on the impact of FELs on pump–probe experiments?

The timescales and intensities provided by FELs have opened up a range of new scientific areas and challenges. We currently don't have a good way to measure the arrival times of the two pulses, which vary from shot to shot. The timing jitter is therefore much larger than the durations of the pulses and the timescale of the experiment. An enormous amount of technical effort is being put into overcoming this issue. Future improvements in synchrotron sources are still important, however, partly because it is so difficult to get beam time at an FEL. Synchrotron sources such as the APS can operate a hundred experiments simultaneously, but X-ray FELs such as the LCLS might only operate one experiment at a time. This makes it very hard to get beam time at an X-ray FEL, although that may change over time. In addition, synchrotron sources and X-ray FELs are very different in terms of their characteristics. Some experiments are better suited to synchrotron sources, whereas others are suited to FEL sources. What I can say is that the LCLS is the most exciting thing to come along in X-ray science since the first synchrotron; it's just fabulous.

INTERVIEW BY DAVID PILE

Stephen Durbin, Tony Clevenger, Tim Graber and Rob Henning have an Article on X-ray-induced optical transmission through GaAs on page 111 of this issue.