# Making LIGHT work of ion beams

**Physicist Markus Roth from the Technische Universität Darmstadt is leading a collaboration dubbed LIGHT to tackle the challenges of transforming laser-based particle acceleration into a viable technology with applications in cancer therapy. Joe McEntee finds out how.**

### Can you tell me more about your collaboration?

Laser Ion Generation, Handling and Transport (LIGHT) is a multidisciplinary research collaboration based in Germany aiming to test potential applications of laser-based particle acceleration. We have six partners – the GSI heavy-ion lab in Darmstadt, the technical universities at Darmstadt and Dresden, Helmholtz centres in Dresden-Rossendorf and Jena, and the Goethe University in Frankfurt. They each bring expertise spanning big lasers, plasma physics, conventional accelerator technology and high-field magnets.

Markus Roth is head of the Laser Ion Generation, Handling and Transport collaboration that is exploring the potential of laser-based particle acceleration.

### How do you accelerate particles using laser light?

The LIGHT team uses GSI's petawatt ($1 \times 10^{15}$ W) PHELIX laser to focus ultrahigh-power laser light onto a thin foil target. This causes massive ionization in the target and expels a large number of relativistic electrons, which leaves the target with a strong positive charge. This creates a transient electric field in which any protons present are then accelerated to high energies.

### What has been the LIGHT collaboration's most recent breakthrough?

This summer we managed to use the PHELIX laser to generate 10 MeV protons from a foil target. What is significant is not the energy of the protons – we achieved 50 MeV and much higher particle numbers a year ago – but the fact that the target chamber has, for the first time, been connected to a conventional ion accelerator. We have now used a focusing ion–optical system to take those laser-accelerated ions and inject them into an existing ion-accelerator beamline here at GSI. This is a big deal because whatever you want to do with laser-accelerated ion beams, sooner or later you will have to manipulate them using more or less conventional ion–optical systems.

### One year into an initial three-year programme with LIGHT, what are the current research priorities?

Clearly we want to be able to capture and control the laser-driven ion beam. Injection and transport over a few metres is important, as is a fundamental understanding of the effects of space charge, beam loading (the feedback of electromagnetic fields on the accelerator at high particle densities) and the interaction of laser-driven ion beams with magnetic fields. Over the next 12 months, we want to inject a laser-driven ion beam into a conventional accelerator beamline and use a radio-frequency cavity to create a monoenergetic beam of high brightness. Control of particle energy is crucial in a lot of the applications we foresee for laser-driven ion beams. In the case of medical applications – proton therapy of deep-lying cancerous tumours, for example – you need an ion beam with very precisely controlled energy spread (less than 1%) to be able to adjust the depth of the radiation dose that gets deposited inside the patient.

### When might such laser-driven ion beams be ready for early-stage clinical studies?

As a scientist familiar with medical applications – specifically the development of carbon-ion therapy here at GSI over the past two decades – I believe that we are looking at somewhere between 10 to 20 years. For therapeutic applications, we will need to demonstrate energies of greater than 250 MeV for protons and 400 MeV per nucleon for heavier ions such as carbon. But there are plenty of other challenges too. High-repetition-rate systems, 24/7 stability as in conventional medical accelerators and improved targetry are all going to be essential. It is worth noting that we have established my univeristy's target laboratory and that we intend to spin that activity out as a start-up within the next 18 months. We also collaborate with Scitech, a spin-out from the Rutherford Appleton Laboratory in the UK, on target materials and design.

### Are you doing basic science as well?

By the end of next year, we plan to have tested the entire laser-fed beamline and to perform the first experiments with a recompressed ion beam that will yield ultrahigh beam powers (hundreds of gigawatts) for materials research at the extremes. We are talking laboratory astrophysics and laboratory geophysics here. By heating tiny volumes of a sample to high temperatures in just a few picoseconds, it is possible

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Researchers inserting a target assembly into the PHELIX laser beamline at the GSI lab in Darmstadt. Earlier this year, the LIGHT team connected the laser-ion-acceleration target chamber to an existing ion-accelerator beamline at the lab.

to create an exciting new state called warm, dense matter. A case in point: we recently published results in *Physical Review Letters* demonstrating the transformation of carbon into the liquid state using a laser-driven ion beam. The high peak current and ultrashort pulse duration (1 ps) of the ion beam enable us to heat carbon to about 5000 K and observe the transformation of the lattice into a kind of liquid. Essentially, what we are trying to do is create extreme conditions in the laboratory that replicate what is going on in the core of giant planets such as Uranus. In terms of fundamental science, that is interesting because we have no idea right now how equations of state evolve under such conditions.

**What about other, more down-to-earth, possibilities?**
There are a number of exciting opportunities taking shape. One possibility being considered is the use of an intense laser-accelerated proton beam as the basis of a fast ignition scheme in inertial-confinement fusion – in other words, to trigger the thermonuclear burn wave that ignites the fuel. There is also interest from the nuclear industry, where laser-driven ion beams and diagnostic techniques such as X-ray diffraction could be combined to evaluate the lattice damage and annealing of materials used in nuclear reactors. Another avenue under investigation is the use of laser-driven ion beams to produce radioisotopes for medical imaging – potentially a more compact and economical option than existing cyclotron or synchrotron technologies.

**So the future's bright for LIGHT?**
Yes, things appear well set. GSI has been an accelerator facility for more than 35 years and now it is really stepping into this regime to figure out what special parameters you can achieve with laser-accelerated ion beams, and also what is required in terms of the enabling technologies for practical applications.

***Joe McEntee is group editor at IOP Publishing.***