Summary of topical discussion on “Laser-accelerator on a chip in Lund?”

Olle Lundh (3/3 2020)

It was invigorating, unusual and fun to have people from so many divisions in the same room, discussing one research topic. Many very interesting questions came up. Here follows a short summary.

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Can the electron source be integrated on the chip?
In current experiments electrons are injected either by an external accelerator, or by field emission from a sharp tip (as in scanning tunnelling microscopy). Ivan and Heiner proposed that maybe one could use laser-field electron-emission from an array of nanowires. This is interesting, in particular because if the array is integrated with the accelerating structure, it would make a truly compact device eliminating the need for delicate electron beam alignment.

Can the laser also be integrated on the chip?
This would be route towards a very compact, turnkey and alignment-free device. However, the discussion indicated that although it is probably possible, it is a too complex problem to be solved in the short-term.

What about multiplexing?
Coulomb forces limit the number of electrons per laser cycle. Torsten proposed that multiplexing, i.e. using multiple parallel micro-channels, could be a way to increase the power and overall yield.

Can one use nanoplasmonics for laser acceleration?
Surface plasmons, have the unique capacity to confine light at the nanoscale. Mattias Borg proposed that it might be interesting to use surface plasmons to: 1) enhance the acceleration field, and 2) to localise the field to areas smaller than the wavelength. This might be beneficial, e.g. for non-relativistic particles which move significantly slower than c.

Can one accelerate positively charged particles (e.g. protons)?
Electrons are easily extracted from a photocathode and have the highest charge-to-mass ratio. Therefore, current experiments study electron acceleration. Geoffrey raised the question whether protons could be laser-accelerated in a microstructure. High-energy protons are the best projectiles for radiotherapy of deep-seated tumours, but currently require large facilities and heavy gantries for beam delivery. A miniature accelerator could be placed in a very compact gantry, in a smaller treatment room.

Can one achieve a small energy spread (%)?
So, far experiments used electron pulses which are much longer than the laser wavelength. Therefore, some electrons are accelerated, and others are decelerated, leading to large energy spread and limited overall energy gain. Small energy spread on the %-level, requires attosecond electron pulses. Can one create, maintain and measure such short pulses?

Can one build structures for significant energy gain (MeV)?
To accelerate electrons to the MeV, require micro-structures with millimetre length. Such structures can easily fit on a wafer and it may therefore be possible to manufacture using today's technology. The difficulty probably lies in keeping the accelerating particles in phase with the driving laser field over an extended length.

What are the most important applications?
In the long-term there might be medical applications. Applications in high-energy physics are also far away. There may be scientific applications in x-ray science. Possibly one might create periodically laser-driven deflecting micro-structures which undulate the electrons so that they generate x-rays.

So, can this research be done in Lund?
I would say the competence is clearly there, so the real question is probably: should this be done in Lund? To find the answer, further discussions about possibilities and goals are necessary.