

Contribution for ICFA Newsletter

The TU-Eindhoven high-brightness program

At Eindhoven University of Technology, the effort on high-brightness electron guns is focused on two goals: injection into a laser wakefield accelerator and conversion of electron bunch energy into coherent transition radiation in the THz-range. The latter is a new subject introduced recently by staff member Jom Luiten. Both goals require bunch lengths in the sub-100 fs range, from a compact gun.

RF photogun and LWFA

As a first step towards such extremely short bunches, we made a number of innovations to the BNL/UCLA/SLAC photogun. Our 2.5-cell version of this gun is now fully operational (Thesis F.B.Kiewiet, TU-Eindhoven, 1 December 2003, ISBN 90-386-1815-8). Using 30 fs UV-pulses, the gun produces 100 pC bunches at bunch lengths around 1 ps and emittance of order $1 \mu\text{m}\cdot\text{rad}$. Our GPT-simulations (postdoc Bas van der Geer) show that at bunch charges of 5-10 pC, bunch lengths of order 50 fs can be expected. Our short-term goal is to inject such bunches into a 100-fs period plasma wave, driven by a 1 TW-laser in a Hooker-type capillary discharge channel. This would lead to a first demonstration of “controlled” wakefield acceleration, i.e. a bunch shorter than the plasma wavelength is accelerated to tens of MeV with final energy spread well below 100%.

High-gradient pulsed-DC fields

In order to further reduce the bunch length, we have been working for some time towards applying to the photocathode a short-pulsed DC gradient which far exceeds the gradient achievable with RF. A laser-triggered 2 MV, 1 ns pulser, delivered in rudimentary state by the NIEFFA Institute, St. Petersburg, has been upgraded by PhD-student Dmitry Vyuga and is currently capable of producing hundreds of reproducible shots per day. The pulser is now coupled to a small diode-gun (3 mm gap) with an electron beam line including a magnetic spectrometer. The latest result is a measurement of 4 MeV electron bunches, produced by field emission from the cathode during the few-hundred ps top of the high-voltage pulse. This

confirms our expectation that doubling of the 2 MV-pulse occurs on the cathode, since it forms an open end to the transmission line. This exciting result, which is based on a 1.3 GV/m gradient, is an important step towards a breakthrough in achievable brightness in photoemitted bunches.

Synchronisation

Before we can start testing photoemission from the pulsed-DC gun, however, the problem of synchronization of the 2 MV-pulse with the Ti-sapphire laser producing the 30 fs UV-pulse, has to be addressed. The jitter of the 2-MV pulse with respect to the trigger laser, presently a 5-ns Nd-YAG laser, is of order 5 ns.

We are engaged in improving the synchronization to less than the 1-ns width of the 2-MV pulse, by using part of the Ti-sapphire output (uncompressed, i.e. at 200 ps) to provide the trigger pulse for the spark gap. This should enable experiments in which photoemitted bunches in the 50-100 fs range can be characterized. For the longer term, we plan to achieve even better control of the 2-MV pulse, the target being risetime and jitter in the 10-ps range. To this end, staff member Seth Brussaard and PhD student Jimi Hendriks are running separate triggering experiments, in which a spark gap, integrated in a co-axial transmission line, is triggered by a cylindrically-focussed TW laser. Current experiments involving 10 kV voltages switched by 40-GW laser pulses, look very promising for achieving the extreme target values. This may eventually open the way to both time-focussing of the bunches and even to multistage acceleration at ≥ 1 GV/m gradients, allowing absolute record brightness.

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