Progress with the 4GLS ERL prototype photoinjector laser system

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Introduction

The design of a laser system to generate bunches of photoelectrons for subsequent acceleration in the 4GLS Energy Recovery Linac prototype was reported last year1). Since then we have commissioned the laser itself, implemented the choppers for time-structuring the beam and designed the hardware needed to attenuate and stretch the individual pulses. In February 2005 the whole system was transported from the CLF development lab, at RAL, to Daresbury, where it was installed in a custom-built laser room (see Figure 1). Further development and testing has continued there.

Laser performance

The laser (High Q Lasers, IC-532-5000) is a modelocked, frequency-doubled Nd:YVO_4 unit, consisting of an 81.25 MHz oscillator, an amplifier to raise the average power to >10 W and an LBO frequency doubler to convert the infrared fundamental to green light at 532 nm. The system was supplied as an integrated whole, when it delivered ~5 W in the green.

The ERLP accelerator needs the cw-modelocked laser beam to be chopped into pulse trains, using a combination of mechanical choppers and a Pockels cell. To minimise the low-level “ghost” pulses which pass through the Pockels cell, the chopping is carried out in the infrared, which involves separating the laser from the frequency doubler. A number of factors arising from this separation and chopping have resulted in a lower green beam power. These include a) losses in the transport optics and in diagnostic beamsplitters, b) astigmatism in the infrared beam, requiring a compromise between frequency doubling efficiency and output beam quality c) some difficulty in optimising the alignment of the infrared beam into the doubler and d) the sensitivity of the doubling efficiency to the LBO crystal temperature which, in turn, is affected by the average infrared beam power. There has also been a reduction of ~1 W in the laser’s infrared output since it was delivered. These effects, in combination, have caused the green power to fall to <4 W (unchopped). However this should still be adequate for effective operation of the ERLP photocathode gun.

Time-structuring system

Delivering the required short pulse trains (<100 μs) means using a high-speed chopper with a narrow slot. The chopper (Terahertz Technologies, C-995) has been fitted with a custom single-slot blade (Scitec Instruments Ltd). Its rotation speed is 100 Hz. To reduce the pulse train rate further it was proposed to cross the high-speed chopper with a slower, variable-rate one. In fact there exist repetitively pulsed shutters which are easier to control and operate than a chopper (particularly at very low pulse train rates). A shutter from nmLaser Products Inc (model LS200) is now in use. The custom chopper blade means that the chopper controller cannot provide a synchronisation signal, so a laser diode/ photodiode combination was fitted into the chopper housing to detect when the chopper opens. The output from the photodiode is divided down and used to open the shutter and to gate the Pockels cell trigger signal. The cell is actually triggered from the (gated) output of a second photodiode which senses the laser pulses. This ensures that the train does not start or end with low-energy pulses transmitted while the cell is switching.

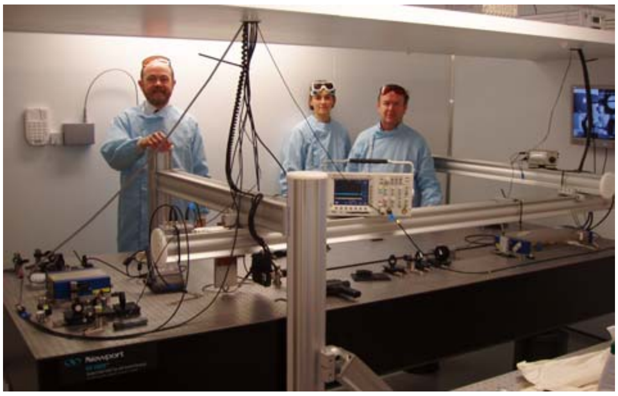

Figure 1. The laser system during installation at Daresbury.

Attenuating and pulse stretching

The ERLP accelerator is designed with an 80 pC electron bunch charge. Variations from this would affect the way the bunch expands due to Coulomb repulsion before it reaches relativistic speed. This, in turn, would alter the bunch transport through the accelerator, leading to collisional losses and to problems with bunch compression. The laser pulse energy is relatively stable, but the quantum efficiency of the Cs:GaAs photocathode in the electron gun changes with time as the cesiated surface degrades. It is therefore necessary to adjust the laser energy, over perhaps an order of magnitude, to keep the bunch charge constant. This is done using an attenuator in the green beam which consists of a motorised half-waveplate and a linear polariser.

The intrinsic duration of the green laser pulses is <6 ps. If the electron bunches were released from the photocathode with this duration the resulting Coulomb repulsion would be unacceptably large. In fact Cs:GaAs is not a prompt electron emitter. There is residual emission for 20-30 ps after the illumination stops, but this bunch stretching may not be enough to control the Coulomb repulsion on its own. Ideally it would also be possible to stretch the laser pulses, perhaps to 20 ps.

Laser pulses can be stretched either by dispersion or by pulse-splitting and stacking. Dispersive schemes may be inefficient and are difficult to implement with the narrow bandwidth of ps pulses. Most stacking schemes generate two separate output beams, each containing only half the initial pulse energy. Recombining these and transporting them more than 10 m to the photocathode would be impractical. The stacking scheme proposed here uses the very large birefringence of YVO_4. Its refractive index difference for e- and o-rays at 532 nm is 0.233, giving a relative delay of ~0.78 ps per mm of crystal length. So a 7.5 mm crystal can generate two orthogonally polarised pulses delayed by ~6 ps. The crystal orientation controls their relative amplitude. A second crystal, 15 mm long and with its fast axis oriented at 45° to the first, can generate a second pair of pulses with a further 12 ps delay. Provided the mixed polarisation is acceptable this scheme promises a simple, stable, efficient, flexible solution to the pulse stretching problem.

References

1. M Divall, G J Hirst and I N Ross,
   CLF Annual Report 2003-2004, RAL-TR-2004-025, 199 (2004)