A COMPACT GHZ LASER FOR A POLARIZED ELECTRON INJECTOR

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1 INTRODUCTION

There is currently considerable interest in using polarised electron beams for nuclear scattering experiments. The polarised electrons are often produced by laser illumination of GaAs type semiconductor photocathodes [1]. Using a CW laser to produce the electrons suffers from two main disadvantages. Firstly, since many accelerators are rf driven, the beam has to be chopped and this results in a small capture efficiency and hence reduced beam current [2]. Secondly, again due to the need for a chopped beam this is an inefficient use of the limited photocathode lifetime. Recently, electron bunches have been produced directly from photocathodes by illuminating them with femtosecond laser pulses [3]. In this case a commercial laser was used and it operated at the 32nd subharmonic of the accelerator frequency. This means the beam current is greatly reduced. There are at present no commercial laser systems that run at the accelerator frequency (typically 2.4 GHz) and produce suitable pulses. We have addressed this problem and constructed a prototype compact laser system that generates pulses that should be suitable, at repetition rates that can be controlled around 2.4 GHz. This system and its performance is described here.

2 SOURCE REQUIREMENTS

The first requirement for maximum efficiency is that the laser operates at the accelerator frequency, which is typically of order 2.4 GHz. Photocathodes have been constructed that operate most efficiently at wavelengths close to 840 nm, which sets the laser wavelength. Furthermore tunability of the wavelength would allow different photocathodes to be used and fine tuning of the photocathode emission. Taking a typical photocathode quantum efficiency of 5×10^{-4}, an average beam current >30 μA could be obtained by illuminating with an optical beam of power 100mW (if it runs at the accelerator frequency). The required laser pulse duration is unclear. An electron bunch duration of less than ~65 ps would be needed at the MAMI accelerator for example [3], but it is not exactly known how the final bunch duration depends on the laser pulse duration.

3 LASER SYSTEM

A schematic of the laser system is shown below in figure 1. It is an external cavity semiconductor diode laser [4]. The compound laser cavity contains two GaAlAs laser diodes and is formed between the back facet of the narrow stripe diode and the front facet of the tapered amplifier diode. The narrow stripe diode is modulated by a high power RF signal (300-400mW) and produces the short pulses, while the tapered amplifier is pumped by a continuous current of typically 1.3A, and gives sufficient optical power output.

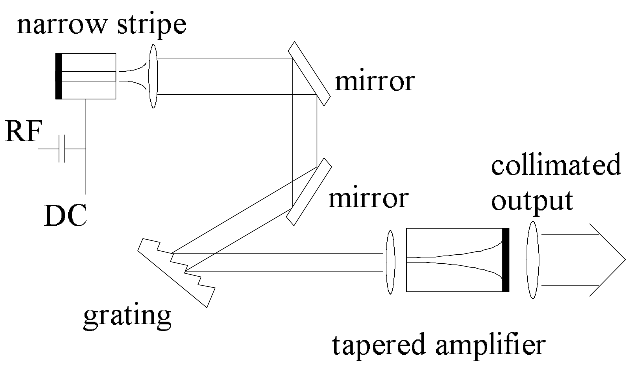
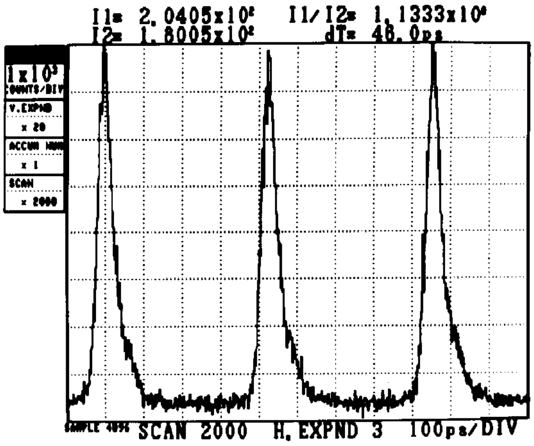


Figure 1. Schematic of Laser Cavity

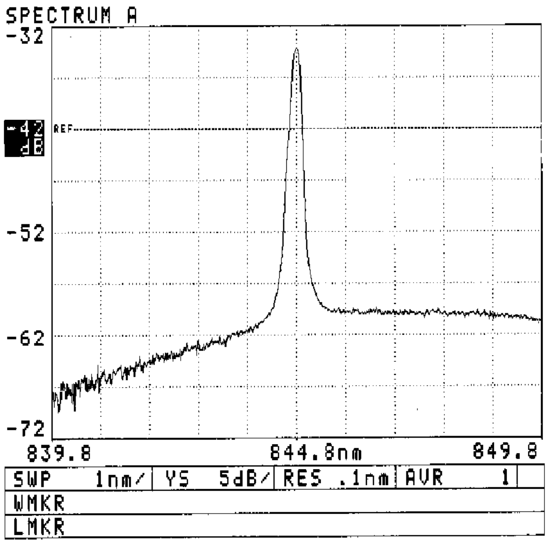
It is not possible to construct a laser cavity which is short enough to produce pulses at the desired rate directly (length = 6.25 cm), so our laser is harmonically modelocked, in this work at the 7th harmonic of the fundamental cavity frequency (340 MHz, length = 44 cm). When used with an accelerator, the accelerator RF signal can be used to drive the laser by setting the cavity length to match the accelerator frequency.

4 RESULTS

Figure 2 below shows a typical temporal profile of the laser output operating at 2360 MHz, with 80 mW average power as measured by a Hamamatsu OOS-1 optical oscilloscope with a resolution of 10 ps and its spectral profile as measures by an Ando AQ-6310C optical spectrum analyser, with a resolution of 0.1nm.



(a)



(b)

Figure 2. Temporal profile at 2360 MHz (a) and spectral profile (b).

The full width half maximum (FWHM) pulse duration is seen to be 46 ps. Operation was also observed at the fundamental frequency and second and third harmonics (340, 680 and 1020 MHz). It should be possible to run the laser at the other harmonics as well, but we could not verify this as our RF amplifiers do not cover this frequency range. Figure 3 below shows a typical temporal profile obtained at 680 MHz (2nd harmonic).

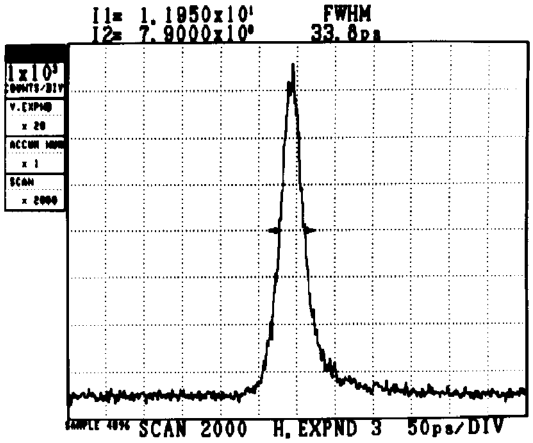


Figure 3. Temporal profile of pulses at 680 MHz

The FWHM pulse duration is measured as 34 ps and the width at 10% of the peak height is 80 ps. The actual duration should be less than this as the 10 ps resolution of the optical oscilloscope is significant here. In figure 4 we show the tuning range at the three different operating frequencies. Note that this curve was obtained only be rotating the tuning element of the laser (the grating in figure 1) with no extra adjustment of the other laser operating parameters.

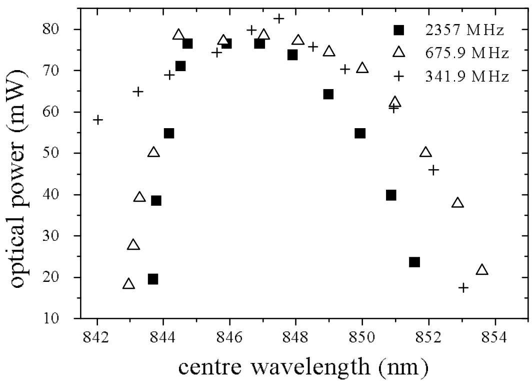


Figure 4. Tunability of laser system

The pulse duration stays below 50 ps for all the curves when the power is above 70 mW. In figure 5 below, the light-current curve at 680 and 2360 MHz is shown. The pulse duration stays below 50 ps for all points.

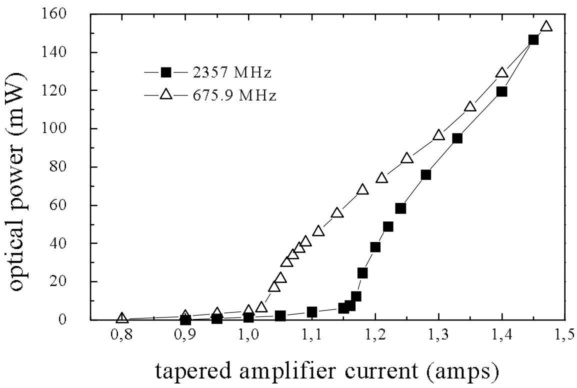


Figure 5. Light-current curve for 680 and 2360 MHz operation

We have also found that the pulse timing relative to a signal can be easily controlled using a phase shifter on the RF laser drive signal with no change to the optical pulse quality. This is displayed in figure 6 below.

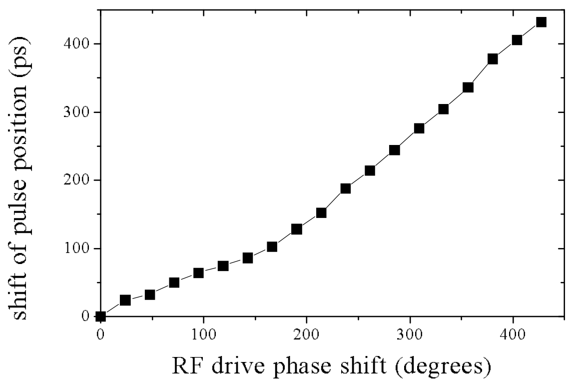


Figure 6. Control of pulse timing for operation at 2360 MHz with pulses of 50 ps duration and 100 mW average power.

5 CONCLUSION

In summary, we have constructed a prototype laser system that generates pulses of duration as short as 34 ps, with powers up to 150 mW at a wavelength of 847 nm with a 4 nm tuning range and repetition frequencies that are multiples of 340 MHz. Different wavelengths can be obtained by selecting laser diodes which can emit over the 780-870 nm range, and are available commercially. Operation of the laser is possible at all the harmonics of the fundamental cavity frequency (340 MHz) up to and including the 7th (2380MHz) which is the accelerator frequency. It could be used at a subharmonic of the accelerator , as there is sufficient optical power to keep the beam current high enough, if a particular experiment needed it (for example higher bunch charge). An important characteristic of this laser is that it is intrinsically timed to the RF drive signal and therefore also to the accelerator.

The next step is to test this laser with a photocathode source to assess the suitability of picosecond optical pulses to produce electron bunches.

6 REFERENCES

1, T. Maruyama et al *Phys. Rev. Lett.*, **66**, 2376 (1991)
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