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MODE-LOCKED FIBRE LASER SYSTEMS INCORPORATING CARBON NANOTUBES AS SATURABLE ABSORBERS

Professor Bill Milne, Dr. Andrea Ferrari and Dr. Alex Rohzin have developed a range of low cost fibre laser systems which incorporate single-wall carbon nanotubes (SWNTs) as saturable absorbers. Compositions of SWNTs are dispersed in optical coupling gels and function as saturable absorbers when introduced into fibre laser systems. As a result of the ultrafast recovery time inherent in these SWNT compositions it is possible to produce mode-locked sub-picosecond laser pulses. Fibre lasers incorporating these SWNT-based mode lockers may be used in a wide range of applications including marking, (ultrafast) microprocessing, medical, sensing, telecommunications and military applications as well as basic research.

Use of these new materials in fibre lasers offers the following advantages:

- tuneability (in practice ~50nm, although in theory up to ~300nm if not limited by the bandwidth of gain media)
- suitable for range of fibre gain media (Yb^{3+}, Er^{3+}, Tm^{3+}, Ho^{3+})
- inexpensive and low-footprint (sub-picosecond recovery time
- ultrawide bandwidth (currently ~300nm, although may be able to cover range 1μm to 2μm)
- mechanically and environmentally robust

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Background

There are three commonly used mode-locking techniques applied to fibre lasers.

Semiconductor Saturable Absorber Mirrors (SESAMs) is the most popular method as it offers great control over device parameters. However, these are inherently slow absorbers, have a restricted operating bandwidth offering tunability over only a narrow range and have poor performance for wavelengths above 1.3 µm.

Nonlinear Polarization Rotation (NPR) offers fast recovery times and wide bandwidth in comparison to SESAMs. However, it is difficult to maintain long term stability with NPR as it relies on polarization and it is not easy to customise device parameters. Moreover, some implementations of NPR are based on free-space optics which are incompatible with fibre lasers.

Nonlinear Optical Loop Mirrors (NOLM) offer fast recovery times and wide bandwidth in comparison to SESAMs but it is hard to characterise or customise device parameters. Moreover, due to the use of long fibres in the cavity, beam stability is poor and bursts of short pulses are produced.

New Technology

Carbon nanotubes are known to exhibit nonlinear optical properties e.g. saturable absorption. This is a phenomenon in which a material's optical absorption decreases nonlinearly with increased intensity and/or power of the incident light, up to a point where the material gets "bleached", i.e. it becomes transparent to the incident light and allows almost unperturbed light transmission.

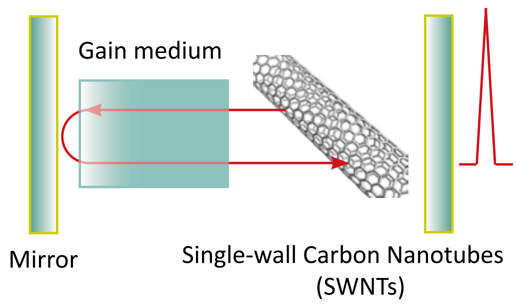

Figure 1: Schematic figure illustrating the non-linear properties of carbon nanotubes

By incorporating a passive mode-locker in a fibre laser system (see Figures 1 and 2) it is possible to have a significant effect on the output pulse. Due to the ultrafast recovery times inherent of the SWNT-doped coupling gels it is possible to produce sub-picosecond pulses by utilising these materials as passive mode-lockers.

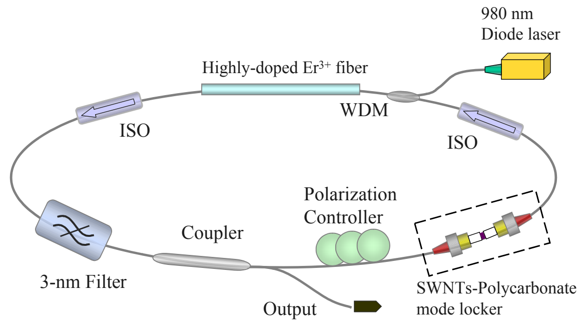

Figure 2: Schematic representation of a fibre laser system including a carbon nanotube-based mode locker

The current operating characteristics of the fibre laser system incorporating the new technology are:

Centre wavelength (λ):	1.0µm – 2.1µm
Tunability:	> 50nm (any λ)
Pulse energy:	65 nJ
Average power:	1.6 W
Peak power:	>40 kW
Pulse duration:	100 fs – 10 ps
Repetition rate:	1 MHz – 100 MHz

The inventors expect to have pulse energies of 1µJ and peak power of around 400kW within six months.

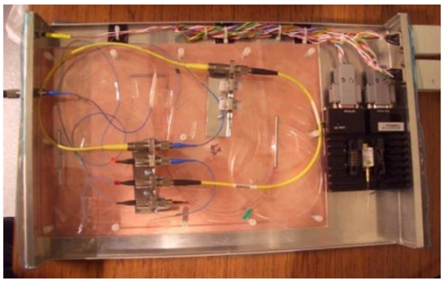

Figure 3: Photograph showing the physical layout of a fibre laser system similar to that illustrated in Figure 2

Commercialisation

We are seeking a commercial partner for licensing, collaboration and development of this technology which is protected by pending US and EP patent applications.

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