The optical spectra of the lasers are single-mode under CW operation, similar to previous reports, and remain nearly unchanged under high-speed modulation, e.g. at 5 GHz's pseudorandom word modulation, up to remarkably high modulation depths as shown in Fig. 3. These dynamic single-mode characteristics are a highly attractive feature with respect to high-speed fibre-optic systems with AlGaAs lasers where the transmission distance is primarily limited by dispersion.

The favourable modulation characteristics of AlGaAs/GaAs MQW RW lasers reported here, combined with the advantages with respect to fabrication and reliability of the structure, may open new application fields for this type of device, as, for example, optical interconnections in advanced computer systems. Further improvement in the high-speed performance may be expected from a reduction of the cavity length and the integration of the lasers with electronic driver circuits on semi-insulating substrates.

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Generation of 2THz Repetition Rate Pulse Trains Through Induced Modulational Instability

Indexing terms: Optical fibres, Optics, Nonlinear optics, Optical modulation

Trains of 100 fs pulses at 2THz repetition rates have been generated through induced modulational instability in a single-mode fibre from an anti-Stokes CW diode laser signal on a carrier frequency provided by a mode-locked Nd:YAG laser.

Introduction: In single-mode fibres the interplay between the non-linear optical Kerr effect and anomalous dispersion, the conditions under which solitons can be observed, can give...
rise to instabilities on CW signals which under certain conditions grow exponentially. This process of modulational instability manifests itself as a spectral modulation of the carrier frequency, and was first observed by Tai et al.\(^1\) in single-mode fibres. In the time domain, soliton-like structures evolve on top of the CW signal with a frequency separation which is inversely proportional to the square root of the fibre dispersion and proportional to the square root of the pump power. Recently, Wang et al.\(^2\) have measured 15 THz modulation rates in femtosecond pulses from a dispersion-compensated colliding pulse mode-locked dye laser operating in the region of low negative dispersion.

Through the application of an external signal, modulational instability can be induced on a carrier wave via frequency mixing, giving rise to ultrashort soliton-like pulses at repetition rates determined by the carrier and applied frequencies.\(^3\) This allows the generation of trains of pulses with repetition rates in the THz regime. These modulation rates are more than one order of magnitude greater than can be achieved electronically or electro-optically.

Modulational instability can play an important role in reducing the required threshold powers for soliton Raman generation in a fibre, with the modulated signals in the Stokes region of the pump receiving preferential Raman gain and evolving into fundamental soliton structures.\(^4\) In this letter we report on the generation of trains of 130 fs pulses at picosecond repetition rates generated by induced modulational instability driven by a CW laser diode operating on the anti-Stokes side of the Nd:YAG laser carrier frequency.

**Experiment:** A schematic diagram of the experimental arrangement is shown in Fig. 1. The carrier frequency was provided by a CW mode-locked Nd:YAG laser operating at 1.319 µm. On the timescale of the expected THz modulation, the 100 ps pulses generated by this laser were effectively CW. A maximum average (peak) power of 2W (200 W) was available from the laser; however, the operational average powers were kept low so as to avoid self-modulational instability from the pump source. A CW GaAlAsP laser diode was used to provide the modulation frequency. This laser was 200 µm long, with plane uncoated facets providing a multimode output centred around 1.307 µm, with an average power of 1 mW. The two lasers, which were orthogonally polarised, were combined using a polarising prism P, and focused into and out of the fibre F, using standard x 10 microscope objectives (MO\(_1\), MO\(_2\)). The fibre sample was 500 m long, single-mode at 1.3 µm with a dispersion minimum in the region of 1.3 µm. On emerging from the fibre, the signal was directed into a spectrograph which had a spectral resolution of 0.1 nm and a second harmonic autocorrelator with a temporal resolution of less than 50 fs.

![Fig. 1 Schematic diagram of experimental arrangement](image)

The laser diode spectrum consisted of several longitudinal modes, depending on the driving current, separated by 1.2 nm. A maximum average (peak) power of 2 W (200 W) was available from the laser; however, the operational average powers were kept low so as to avoid self-modulational instability from the pump source. A CW GaAlAsP laser diode was used to provide the modulation frequency. This laser was 200 µm long, with plane uncoated facets providing a multimode output centred around 1.307 µm, with an average power of 1 mW. The two lasers, which were orthogonally polarised, were combined using a polarising prism P, and focused into and out of the fibre F, using standard x 10 microscope objectives (MO\(_1\), MO\(_2\)). The fibre sample was 500 m long, single-mode at 1.3 µm with a dispersion minimum in the region of 1.3 µm. On emerging from the fibre, the signal was directed into a spectrograph which had a spectral resolution of 0.1 nm and a second harmonic autocorrelator with a temporal resolution of less than 50 fs.

In the time domain interference between the frequency components should give rise to the evolution of a pulse train. The background-free autocorrelation corresponding to the experimental situation of Fig. 2b is shown in Fig. 3. On the broad pump pulse profile of approximately 100 ps, trains of femtosecond pulses separated by 4.6 ps had evolved. The 4.6 ps separation corresponds within experimental error to the 4.7 ps inferred from the 1.2 nm spectral separation of the modes of the diode laser. Around the peak of the autocorrelation a 50% modulation depth was measured. This would suggest that the central region of the generated pulse train in real time would be effectively 100% modulated.\(^3\)

![Fig. 2 Output spectra from 500 m long single-mode fibre for input of (a) 70 mW average power at 1.319 µm from Nd:YAG laser, and (b) 70 mW average power at 1.319 µm plus 300 µW at 1.307 µm from diode laser](image)

Output spectrum from diode laser is shown in Fig. 2a for reference.

In the time domain interference between the frequency components should give rise to the evolution of a pulse train. The background-free autocorrelation corresponding to the experimental situation of Fig. 2b is shown in Fig. 3. On the broad pump pulse profile of approximately 100 ps, trains of femtosecond pulses separated by 4.6 ps had evolved. The 4.6 ps separation corresponds within experimental error to the 4.7 ps inferred from the 1.2 nm spectral separation of the modes of the diode laser. Around the peak of the autocorrelation a 50% modulation depth was measured. This would suggest that the central region of the generated pulse train in real time would be effectively 100% modulated.\(^3\)

![Fig. 3 Background-free autocorrelation trace of induced modulational instability pulse train](image)

- Corresponding to experimental conditions of Fig. 2b
- Autocorrelation of pulse train on expanded timescale
Pulse repetition rates should be possible. The individual frequency separations between the carrier and signal, higher than those generated, were feasible. The modulation depth at the centre of the pump approached 100%. This technique provides a simple mechanism which causes minimum aperture field distortion and an axisymmetric beam can only be obtained with a balanced hybrid mode condition.

The best design, which is illustrated in Fig. 3b, was highlighted by a series of experiments which compared the measured VSWR performance is shown to be significantly better than that for the horn shown in Fig. 1a.

**Introduction:** High-quality reflector antenna systems commonly employ corrugated horns as primary feeds. The main disadvantages of this horn type are the complexity of the design procedure and the high cost of manufacture. An alternative to the corrugated feed is the dielectric core horn, which exhibits excellent radiation characteristics over wide bandwidths.1 The simple design requirements and the relative ease of fabrication make the dielectrically loaded horn an attractive option for use, particularly at millimetric frequencies.2

Low crosspolarisation and an axisymmetric beam can only be generated if the width of the low-permittivity layer surrounding the dielectric core is chosen to be of a magnitude such that the balanced hybrid mode condition is satisfied.

Futhermore, to maintain good polarisation purity it is essential to minimise the presence of the core support structure in the gap cross-section. In a previous letter3 this point was highlighted by a series of experiments which compared the linear crosspolarisation of a partially filled dielectric horn using three different methods to hold the core concentric with the metal horn wall. The best design, which is illustrated in Fig. 1a, was shown to generate radiation patterns with good axial beam symmetry and peak crosspolar levels below −33 dB at 94 GHz. This design probably represents the best option for reducing the field degradation caused by the presence of the inner core support structure. However, its use in a practical system is limited by the inability of the host horn to secure the dielectric insert firmly.

In this letter we identify a practical design for the support mechanism which causes minimum aperture field distortion and provides high mechanical strength. Furthermore, the

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