Proceedings Paper:

Wang, F, Nong, H, Fobbe, T et al. (14 more authors) (2017) Short THz pulse generation from a dispersion compensated modelocked quantum cascade laser. In: International Conference on Infrared, Millimeter, and Terahertz Waves, IRMMW-THz. IRMMW-THz 2017, 27 Aug - 01 Sep 2017, Cancun, Mexico. IEEE . ISBN 978-1-5090-6050-4

https://doi.org/10.1109/IRMMW-THz.2017.8067123

Short THz pulse generation from a dispersion compensated modelocked quantum cascade laser

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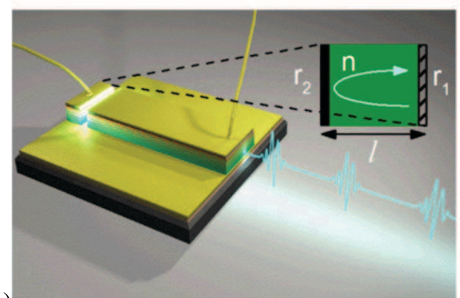
***Abstract*— Dispersion compensation is vital for the generation of ultrashort and single cycle pulses from modelocked lasers across the electromagnetic spectrum. However, no such scheme have been successfully applied to terahertz (THz) quantum cascade lasers (QCL) for short and stable pulse generation in the THz range. Here we show a monolithic on-chip compensation scheme for a modelocked QCL, permitting THz pulses to be considerably shortened from 16ps to 4ps. This is based on the realization of a small coupled cavity resonator that acts as an 'off resonance' Gires-Tournois interferometer (GTI), permitting large THz spectral bandwidths to be compensated.**

I. INTRODUCTION

In the terahertz (THz) frequency range (~ 0.5 - 5 THz) , a semiconductor based technology platform for intense an ultrashort pulse generation has yet to be realized. This is in contrast to the optical and near-infrared (NIR) domain where ultrashort pulse generation can be readily achieved in devices such as mode locked semiconductor diodes and vertical external cavity surface emitting lasers (VECSELS). [8–10] Although THz quantum cascade lasers (QCLs) are a foundational semiconductor laser in the THz range, to date, the generation of stable and ultrashort pulses from QCLs has proven to be difficult. These devices, first realized in 2002, [1] permit the frequency, and bandwidth to be entirely engineered. Active mode locking, where the device is electrically modulated at its' roundtrip, has been extensively applied but the pulses generated so far have been limited to the range of 10ps to 20ps, despite several years of research effort. [2,3] Although THz QCLs with extremely large gain bandwidths have been realized leading to impressive developments in frequency comb generation, [4,5] this has not translated directly into the formation of stable short pulses in the THz range, although single pulses of 2.5ps have been shown [6].

Here, we resolve the THz QCL short pulse bottleneck through a novel on-chip geometry that permits the GDD of the QCL to be compensated, leading to considerably shorter pulses when the QCL is active mode locked. This is realized through the monolithic integration of a small resonator at one end of a 2.5 THz QCL cavity (shown schematically in figure 1, based around a Gires-Tournois Interferometer (GTI) approach that adds an opposite dispersion to that of the material. By judiciously designing the length of the integrated GTI and applying the GTI 'off-resonance', significant compensation of the QCL's inherent GDD can be realized. This directly results in pulse durations as shorts as 4 ps, from 16 ps with a standard QCL geometry (fig 1b). As the GTI is used 'off-resonance' and not in the typical 'on-resonance' case, this relatively simple approach can be easily scaled to compensate for even greater spectral bandwidths and potentially attain sub-picosecond pulse widths.



(a)

(b)

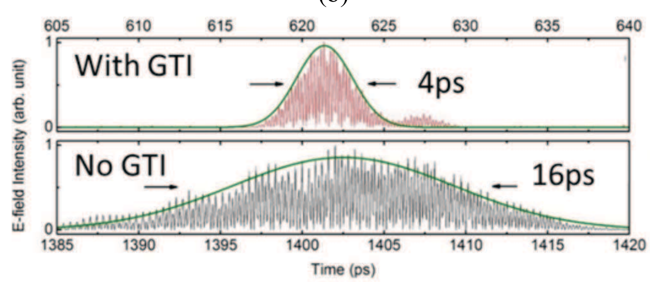


Fig. 1. a) **GTI schematic** a) Schematic of the GTI coupled to a QCL to realised ultrashort THz pulses. The inset represents the GTI with asymmetric reflectivities, r_1 and r_2 and a cavity length, l. b) **Short Pulse generation from THz QCLs.** Comparison of a QCL with a GTI (red) and a standard QCL cavity (black).

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