**Temporal Dynamics of THz Quantum Cascade Laser**

**Frequency Combs with Strong Injector Anticrossing**

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We investigate the temporal dynamics of terahertz (THz) quantum cascade laser (QCL) frequency combs with a strong injector anticrossing via numerical solution of the Maxwell-Bloch laser equations [1].

The presence of a strong anticrossing between the injector and upper laser levels of the experimental device in [2] leads to a pronounced splitting of the emission spectra into high and low frequency lobe components around the central frequency of 3.5 THz. Moreover, such an effect also manifests itself in the time domain as a form of pulse switching between signals corresponding to the two lobes of the split gain, as experimentally observed in [3]. This process was explained as a form of temporal hole burning. Here we present a theoretical model, based on coupled density matrix/Maxwell equations, which can correctly account for that effect.

Fig. 1 **a** High and low frequency pulses computed over the last 35 out of 104 simulated round trips for a numerically dispersion compensated THz QCL. **b** The same as the data in the left column, however this time from simulations of a dispersion uncompensated laser. The dispersion compensation in **a** was implemented in the frequency domain by Fourier transforming the electric field and removing the undesired higher order phase acquired after each propagation step.

30

30.5

31

31.5

32

32.5

33

Time (normalized to Trt )

0

4

8

High freq. lobe

Low freq. lobe

30

30.5

31

31.5

32

32.5

33

Time (normalized to Trt )

0

4

8

Intensity (a.u.)

0

4

8

1

1.5

2

2.5

3

3.5

4

Without disp. comp.

0

4

8

1

1.5

2

2.5

3

3.5

4

With disp. comp.

Intensity (a.u.)

**b**

**a**

We simulated the THz QCL comb in [2] for the two distinct cases when there is weak and strong chromatic dispersion and our results are depicted in Fig. 1a and Fig. 1b, respectively. In both plots the mentioned pulse switching behaviour is clearly visible, and we also notice a more prolonged pulse duration for the signal corresponding to the high frequency spectral component. Density matrix calculations reveal that this dynamics could be due to alternating saturation of the symmetric and anti-symmetric dressed states [4], which are responsible for the low and high frequency radiative transitions, respectively. Furthermore, comparing the plots in the right and the left column of Fig.1, we can clearly see that the presence of strong chromatic dispersion disturbs the periodicity of the signal, as the high and low frequency lobe components seem to constantly “compete” with each other, thus introducing a strong timing jitter in the overall signal. The dependence of this process on different model parameters such as bias, anticrossing strength, chromatic dispersion etc. will be thoroughly discussed and possible methods for its utilization for frequency comb characterization will be considered.

**References**:

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