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Comprehensive study of dynamic behavior of nonlinear dispersive quantum-cascade lasing medium under different cavity configurations

Since the first demonstration in 1994, quantum-cascade lasers (QCLs) have become one of the most important solid-state mid-infrared (MIR) coherent light sources for various applications in environment sensing, medical diagnosis and free-space communication. The dynamic analysis of MIR QCLs is crucial for QCLs to have reliable performance in these applications. An explicit description of the dynamics of QCLs is inevitably complicated when compared to conventional lasers because of the unique combination of ultrafast carrier scatterings and gain recovery, significant nonlinearities and dispersion effect in a QCL medium. However, the group-velocity dispersion (GVD) has not been explicitly addressed in the study of dynamic behaviors in QCLs. In our study, we carefully examined the effect of GVD on the pulse progression in both time and frequency domains as well as the interplay between GVD and self-phase modulation (SPM) in the cavity. Moreover, we carried out the study for QCLs with both ring and Fabry-Perot (FP) cavities. Comparisons of QCLs' behaviors in the two types of cavities manifest the influence of spatial-hole burning (SHB) which is only supported in a FP cavity but not a ring cavity. We found out from our simulation that the SPM and GVD have cancellation effects in the time domain. In the frequency domain, they affect the spectrum in different aspects. The anomalous GVD effect excites the symmetric side modes around the central mode. The SPM broadens the line width of each mode, but it does not change the spectral spacing among exited modes. When co-existing in the lasing medium, both GVD and SHB induce side modes, though, through two different mechanisms, i.e., the lasing instability of the former and the gain saturation of standing waves of the later. The pair of modes due to SHB has much closer spectral separation and higher peak intensity than those by GVD.

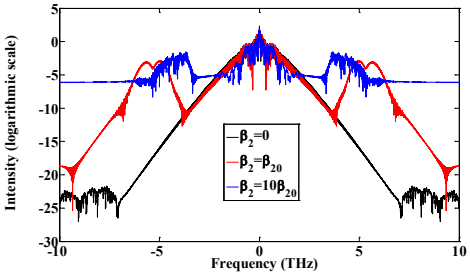

Figure-1: Optical spectrum versus GVD strength (β2).

Recent Publications

1. D Zhou, H Wang and Jing Bai (2017) Conformable pressure sensor array based on silver nanowires and PDMS for electronic skin application. *Sensor Letters*; 15(1): 11-18, J.
2. J Bai, H Wang, Q Wang, D Zhou, K Le and B Wang (2016) Coherent pulse progression of mid-infrared quantum-cascade lasers under group-velocity dispersion and self-phase modulation. *IEEE Journal of Quantum Electronics*; 52(9).

Biography

Jing Bai is a tenured Associate Professor and the Director of Graduate Studies in Department of Electrical Engineering at the University of Minnesota Duluth (UMD), where she started working as an Assistant Professor in 2007. She has received her PhD degree in Electrical and Computer Engineering at Georgia Institute of Technology in 2007. Her current research activities focus on nanoscale optoelectronic and photovoltaic devices, biomedical devices and nonlinear optics. She has received the SCSE Young Teacher Award in UMD in 2012. She is a Member of the Institute of Electrical and Electronics Engineers (IEEE), IEEE Women in Engineering (WIE), the Optical Society of America (OSA), the American Physics Society (APS) and the International Society for Optical Engineering (SPIE).

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