QUANTUM CASCADE LASERS AND INJECTION LOCKING

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Abstract: Quantum cascade laser (QCL) is a new type of laser, first demonstrated in Bell Labs. in 1994, where a photon is emitted due to intraband transition of electrons. In normal injection lasers, a photon is emitted when an electron jumps from the conduction band to the valence band. So, it is an interband transition. In QCL, a single electron slides down a stair case-like potential in the conduction band leading to the generation of a cascade of identical photons. The existence of sub-bands in the conduction band in a super-lattice makes it possible to create a stair case-like potential. These lasers (QCL) can lase in the Mid Infra red (IR) region and also in the terahertz (THz) region. QCL is unipolar in contradistinction to normal pn junction laser which are bipolar.

The phenomenon of injection locking, where a master QCL controls the phase and frequency of a slave QCL, finds potential applications in Mid IR communication systems such as amplification of angle-modulated IR signals, frequency modulation (FM) to intensity modulation (IM) conversion, demodulation of angle-modulated IR signals, suppression of relative intensity noise (RIN) of the master QCL, etc.

The author has developed a unique theory of injection locking of QCLs which is based on transmission line model. The conventional theory of injection locking of semiconductor lasers is based on laser rate equations. There appears some difficulty in treating the injection locking phenomenon on the rate equation model. A key factor which can influence the injection locking process in QCL is the line width enhancement factor (LEF).

The LEF can have profound effect on the frequency response characteristics of the injection locked QCL. Angle-modulated Mid IR signals can be amplified through injection locking of QCL, and the LEF can have considerable effect on the QCL amplifier performance. The output phase modulation of the locked QCL falls with increasing modulation frequency. This fall is arrested by the LEF. The higher the value of LEF the lesser is this fall with modulation frequency. Also, the higher the locking signal power, the lesser is this fall in phase modulation response of the injection locked QCL.

Amplification of two-tone angle-modulated IR signals and the same of subcarrier multiplexed (SCM) angle-modulated IR signals have been investigated keeping the intermodulation distortion (IMD) level under control.

Demodulators for Mid IR PM signals are difficult to design. Injection locked QCLs can convert the input Mid IR PM signal into corresponding IM signal and the latter can be detected by a photodetector. The dependence of PM-IM conversion on physical parameters such as modulation frequency, injection power level, value of LEF have also been investigated.