Classical corpuscular optical theory of squeezed states of light

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Summary

Semi-classical theory of semiconductor laser noise considers the spontaneous emission fluctuations as the major noise source [1]. Arnaud has recently proposed a description of semiconductor laser noise without quantification of the optical field where the fundamental noise source is the shot noise associated with the field to absorbing atom conversion [2]. We propose a classical corpuscular theory in which a laser beam is considered as a flow of classical particles without mutual interaction. The intrinsic field fluctuations are described as the shot noise associated with the photon production or absorption. The noise linked to mirror losses is taken into account in the form of partition noise [3]. It can be represented by a partition Langevin noise force linked to laser facet reflections as in figure 1.

![Figure 1: Model of partition noise](image)

The langevin noise force satisfies the relations:

\[
\langle f_\rho(t) \rangle = 0 \quad \text{and} \quad \langle f_\rho(t) f_\rho^*(t - \tau) \rangle = \bar{\rho}^2 \delta(\tau) = \bar{\rho} R (1 - R) \delta(\tau)
\]

where \( \langle \rangle \) represents the time average, \( R \) the laser power reflection coefficient and \( \rho(t) \) the photon flux. In this representation, as for vacuum fluctuation the anticorrelation of the reflected and transmitted powers provide a feedback signal which can correct the fluctuations resulting from the partition noise. Such a noise force is to be used for the laser facet reflection but also for the noise associated to the non-resonant internal loss, which can also be described by a beam splitting.

Fluctuations of the stored energy and emitted power of a semiconductor laser are derived with this description [5]. The theory allows the description of the non-classical states of light, and its results agree with quantum theory. For quiet pumping conditions [4] and for a high reflection coated Fabry-Perot laser, 50% of internal photon noise suppression is obtained. For high power and low frequency, the output photon noise is determined by the ratio between the overall photon lifetime and the mirror loss photon lifetime. For low internal loss, it can be reduced below the shot noise limit as presented in figure 2.

The effect of attenuation on the propagation of a laser fluctuations inside an absorbing medium is studied using the concept of partition noise. This leads to the invariance of a suitably defined Relative Intensity Noise. To describe sub-Poissonian photon statistic a negative Relative Intensity Noise is formally introduced [6]. The semiconductor laser noise measurement with the
The dual balanced detection technique is analysed using optical partition noise showing the optimum conditions for the squeezed light measurement.

![Diagram of External Amplitude Noise](image1)

**Figure 2:** Normalized external amplitude noise for various values of internal loss

The low frequency intensity noise and the associated shot noise of a 1.55 mm compressive strained MQW DFB laser are measured with a dual balanced detection technique. Experimental results are presented in figure 3. The laser operates at room temperature and demonstrates 4 dB amplitude squeezing under quiet pumping conditions. Such efficient squeezing is achieved through an additional negative electrical feedback.

![Diagram of Intensity Noise](image2)

**Figure 3:** Intensity noise measurements of a 1.55 mm DFB laser

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**References**