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Intensity Squeezing in Semiconductor Lasers *

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Intensity squeezing is generated in single mode semiconductor laser by weak external mirror feedback. The measurable squeezing is 4.7%, corresponding to 9% below the SNL after correction for transmission and detection efficiency. It proves that intensity squeezing can be obtained at room temperature without line-narrowing techniques.

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Squeezing in semiconductor lasers has been extensively studied since its first realization by Y.Yamamoto and his co-workers in experiment in 1987[1]. Ideal intensity squeezing, that is, the Fock state, has been known to have the largest capability in optical communication and has great potential use because of the campactness, energy efficiency and tunablity of the semiconductor lasers. However, intensity squeezing in semiconductor lasers can be obtained usually at the very low temperature. The best squeezing accomplished by W.H.Richardson et al[2] in 1991 was 87%, which was obtained at 66K. In 1993, it was shown by D.G.Steel and his group[3] that some line-narrowing techniques, such as grating feedback or injected-locking, greatly helped in the noise reduction and intensity squeezing can be obtained at room temperature. By using grating feedback, 41% squeezing was obtained by T.C.Zhang[4]. However, large loss with grating feedback damage the output squeezing and one can not bring the high quantum efficiency of semiconductor laser into full play. In 1994, J.Kitching[5] proved theoretically that intensity squeezing could be achieved through weak external feedback and, according to J.Kitching, it appears that it is unnecessary to use the complex line-narrowing techniques to realize the squeezing. In this talk, we report the experimental result of realization of intensity squeezing in single mode semiconductor lasers through weak external mirror feedback.

The semiconductor lasers are index-guided quantum well GaAlAs laser diodes (model SDL-5411-G1) operating at 850nm. The rear facet reflection coefficient is 95%, the front facet is AR coated with a reflection coefficient of about 4%. The free-running laser diodes have threshold of 20mA and its intensity noise is usually 2 to 5 dB above the shot noise level(SNL). The whole experimental setup includes a LD with high impedance source pumping. and is actively temperature-stabilized around room temperature(20^0C). A collimating lens with f=7.5mm objective placed in front of the output facet of the diode. BS1 is a beamsplitter with a reflection coefficient of 10%. M is a plane mirror with a reflection coefficient of 15% and it is glued on a piezoelectric transducer(PZT) which is mounted on a finely oriental mirror mount. Consider to feedback coupling, the feedback coefficient in the system is less than 0.1%. The balanced detection[6] consists a 50-50 beamsplitter and two photodiodes with about 81% of quantum efficiency(EG&G model FND100). The consistency between the shot noise of a semiconductor laser measured by the balanced detection and the noise of a white light source was carefully

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calibrated. Same photocurrent from the white light source and the laser diode should have the same shot noise level. At detector current up to 12mA, the shot noise level at 18MHz calibrated with white light and laser was found to be linear in the DC photocurrent to within 1%.

In experiment, one must adjust the lens L1 and OI to let the beam collimating and to avoid feedback. Align the mirror to get the maximum thrshould shift which can be monitored by scanning the driving current. By changing the DC voltage biased on the PZT, one can control the phase of feedback light and find the optimal noise of the intensity.

The laser diode operates at 80.30mA with the 8mA of photocurrent of each photodiode, the current-to-current differential efficiency is about 30%. The result shows, when corrected for the electronic noise, the intensity noise is 0.21dB lower than the SNL, which corresponds to 4.7% of squeezing. Consider 65% of the total transmission efficiency and the quantum efficiency of photodiodes(81%), the intensity squeezing of output beam is actually 9%. We also measure the noise from 9KHz to 20MHz and find that squeezing exists from about 10MHz to 20MHz. But for higher frequency, the measurement is limited by the amplifier.

In conclusion, intensity squeezing in single mode laser diode by weak external mirror feedback is obtained. Although the squeezing is not so high, it is simple and reliable to achieve. The weak feedback overcomes the large loss in grating feedback. The overall quantum differential efficiency is 30% but we obtained only 9% of squeezing, this means that there are some excess noise which, according to recent experiments by J.Kitching[7] and F.Marin[8], comes from the power of the side-mode. But how the side mode generate the excess noise is not clear yet. Our result shows that the simple device, mirror, which is not a frequency selective device, can also cause the side mode suppression.

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