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Elimination of Excess Photon Noise from Fibre Super-Radiant Sources

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Abstract

High-power incoherent sources such as ELEDs and rare-earth-doped superfluorescent sources exhibit excess photon noise which limits their application in sensors such as the fibre-optic gyro. We show that this form of noise can be eliminated by a compensation scheme.

Summary

It has recently been shown[1] that high-power superluminescent sources such as required for the Fibre Optic Gyro and other sensor applications have an excess noise component which prevents the SNR increasing beyond a fixed value. The excess noise is inherent in the thermal nature of the light and will always be present for thermal-type sources. Since with the higher power sources now available the excess noise can be considerably larger than the fundamental shot-noise limit, the question arises whether this type of noise can be eliminated using a form of compensation. Such a scheme requires the noise to be correlated on two detectors.

In this work we have investigated the temporal correlation of noise signals obtained by dividing the 1.535μm output of a superluminescent erbium-doped germano-silica fibre source onto two detectors. The source consisted of a 7.5m length of fibre (NA 0.17, cutoff 975nm, 60ppm molar dopant concentration) which was pumped at 980nm with light from a Schwartz Electro Optics Ti:Sapphire laser (Figure 1). The output end of the fibre was polished at a 10° angle to prevent feedback. Approximately 3mW of unpolarised light at 1.535μm in a spectral bandwidth of ~2nm was obtained. Figure 2 shows the spectrum of the source output. Further details of the fibre source can be found elsewhere[2]. A single polarised mode of the output was isolated with a polariser. The signal power was varied with an attenuator and a pellicle

was used to divide the signal approximately equally onto two InGaAs detectors (Epitaxx ETX300). The output from the detectors was applied to a noise compensation circuit consisting of two pre-amplifiers, one DC-coupled (signal channel) and one AC-coupled (reference channel) both connected to a unity-gain difference amplifier. The output DC signal level was monitored while the noise was simultaneously determined using an RF spectrum analyser. The set-up had an electronic bandwidth of ~1MHz. A dividing circuit could equally have been used for noise compensation.

Figure 3 shows the measured noise power at 100kHz as a function of signal level, both with and without the reference channel active. Without the reference channel (squares) the noise power $\langle \Delta I \rangle^2$ follows closely the excess-noise theory, curve A, predicted for a polarised thermal source, ie $\langle \Delta I \rangle^2 = 2\langle I \rangle^2 B/\Delta\nu$ where I is the detector photocurrent, B is the measurement bandwidth and $\Delta\nu$ is determined by the optical linewidth of the source. Note that the power SNR does not increase with increased signal power.

Subtraction of the reference channel gave rise to a characteristic shown by the circles in Figure 3. Curve C shows the calculated shot noise for a single detector and curve D the shot noise for the two detectors together (+3dB), which is the minimum noise expected for this configuration. We see that with the noise compensation active (curve B), the experimental data is only 1-2dB above this quantum limit.

With compensation, the experimental data for noise power increases with (signal power)$^{0.5}$ and the SNR therefore increases with received signal power.

We have shown that compensation of super-radiant source excess noise is possible using a simple referencing scheme. In this experiment the noise power was reduced by as much as four orders of magnitude to within 2dB of the quantum limit. Thus operation of sensors at high SNR with only a minimum of extra complexity is possible with high power super-radiant sources.

References

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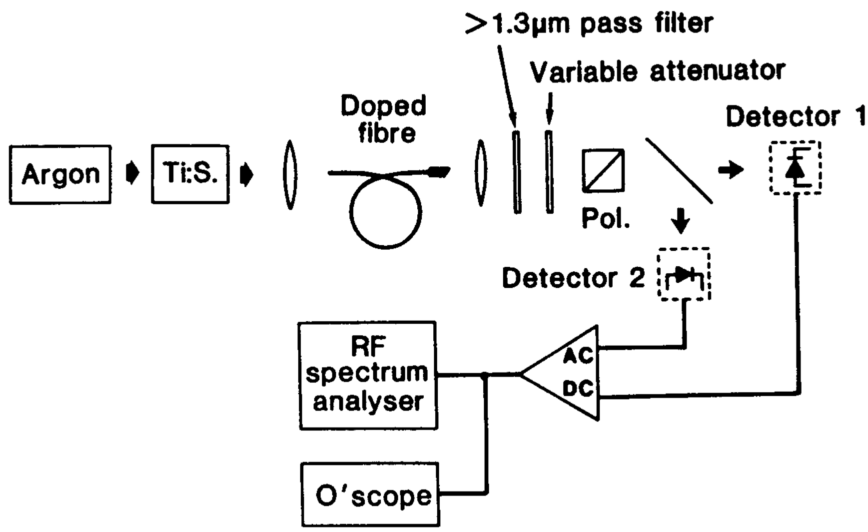

Figure 1 Experimental set-up.

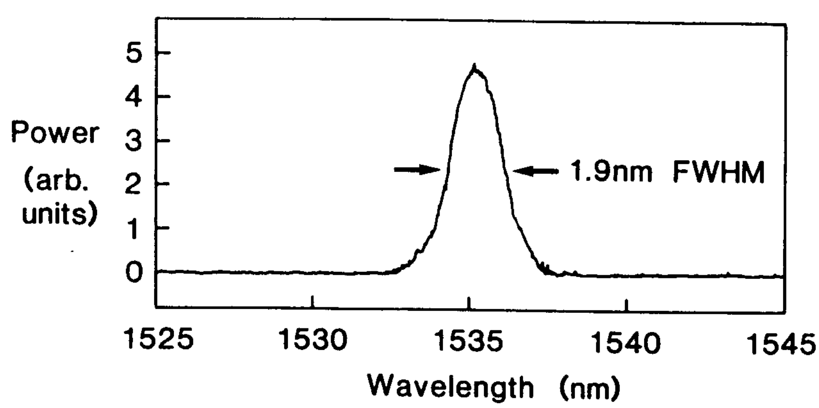

Figure 2 Super-radiant output spectrum @ 1.535μm. 0.2nm resolution.

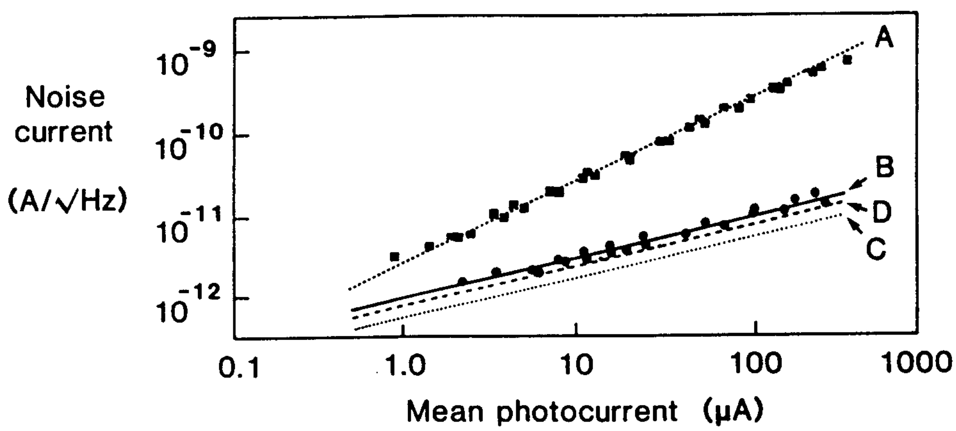

Figure 3 Noise characteristic without compensation (squares) and with compensation (circles).