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TOWARDS AN EFFECTIVE REDUCTION OF INTENSITY NOISE IN LASER DIODES

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Lasers are ubiquitous in laboratory setups, including the actuation and sensing of micro- and nanomechanical systems. An example of this, is the optical beam deflection (OBD) technique, that is used to measure to rotation of a surface [1]. In this technique, the surface is illuminated using a beam of light, that is reflected onto a position sensitive detector (PSD). As the angles of incidence and reflection change with rotation of the surface, the reflected beam moves across the surface of the PSD.

The incident light is not fully reflected, as some passes through the sample and part of it is absorbed. The absorbed energy causes thermal gradients in the sample, that can cause it to deform due to the induced thermomechanical strains.

The incident light intensity fluctuates in time, and consequently so do the absorbed and reflected power. In OBD systems, this can have an effect in two ways: 1) fluctuations in the reflected power cause additional noise in the PSD signal and 2) the microsystem itself is affected by the induced thermal gradients.

Although a discussion of the origins of intensity fluctuations in laser diodes is outside the scope of this manuscript, it is instructive to highlight that these can be caused by changes in the shape and the dimensions of the laser cavity (for example by thermal drift) and by optical feedback [7]. In the latter light is fed back into the laser cavity from the outside.

This is one of many examples, in which laser intensity noise disrupts optical measurements of micro- and nanomechanical systems.

It has been suggested in literature, that in laser diodes these fluctuations can be reduced by a technique called high frequency injection (HFI) [2][3][4]. A high frequency signal of several hundred MHz is superimposed on the drive current that powers the laser diode. Although not fully understood, it is believed that this excites the diode in a state of multimode emission. Theoretical research shows that this makes the system more robust against optical feedback [4].

An effective implementation of this technique, however, is not without challenges [5][6] and can have a major impact on system design as we demonstrate in this manuscript. The naïve implementation of HFI on an existing OBD system, exposes the issues concerning the implementation.

The first problem lies in finding the right excitation frequency. This frequency is diode dependent and needs to be determined experimentally by means of a tunable radio frequency (RF) signal generator. As shown in Fig. 1 the higher frequency components that originate from these generators, can be strong enough to excite the laser diode. Although using steep low-pass filters with a well chosen cut-off frequency can reduce these effects, it is clear from Fig. 2 that the reduction is of minimal effect.

The second problem lies in the embedded spatial filtering. Many applications benefit from the Gaussian beam profile that is created by the primary mode of the laser diode. In a multimode system, however, the ratio between the different modes is continuously changing. A consequence of this is a fluctuating beam

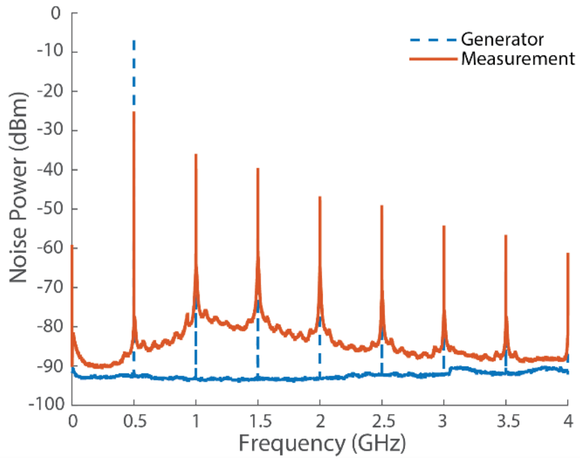

Fig.1: Shown in red is the measured noise spectrum of the laser diode. Shown in blue is the measured output spectrum of the generator. Although the generator is set to a single frequency of 500 MHz, it is clear that higher harmonic components that are present in the signal excite the laser diode.

profile on the PSD. This result of this is a higher noise level from the PSD [5] compared to that for a single mode laser. For this reason, many diodes are pre-aligned and integrated with a single mode fiber, which only allows the primary mode to propagate. This limits any effects of multimode interactions to the laser cavity. The noise reduction through mode partition [7] is therefore not observed.

For HFI to be effective, one requires high suppression of spurious modes of the injected RF signal, proper choice of signal amplitude [3] and frequency. A reduction of intensity noise may be achieved, at the price of a fluctuating beam shape.

Therefore, we conclude that HFI is not universally applicable and requires a-priori consideration of the system architecture. We therefore recommend that low noise, incoherent sources are considered first, in conjunction with optical isolators, rather than applying HFI as a tool to reduce intensity noise in an existing system.

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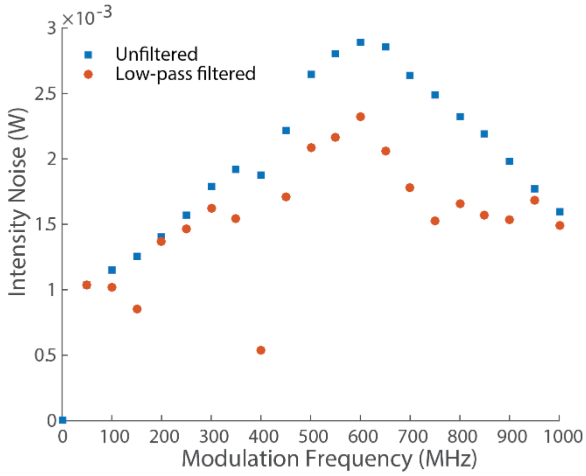

Fig.2: Shown is the root-mean squared intensity noise as function of modulation frequency, measured over a a bandwidth of 4 GHz. The case in which the signal is directly injected from the signal generator and the case in which the signal is pre-shaped used a steep low-pass filter are represented by blue squares and red circles, respectively.

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