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An approximative cavity dispersion assessment technique using dispersive mode-locked cavity wavelength tuning

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Abstract: This paper demonstrates that without any additional elements necessary for wavelength tuning, dispersion in a mode-locked cavity can be assessed. The procedure described delivers dispersion results in agreement with already known dispersion values.

1. Introduction

One type of laser source for swept source optical coherence tomography (SS-OCT) [1] is based on active mode locking method with dispersive fibre cavity [2]. SS-OCT regime has shown the highest imaging speed in the OCT methods and has been used to the medical as well as non-medical imaging. The sweeping method presented is based on the dependence of wavelength tuning rate on the dispersion in the cavity and the RF modulation frequency of the signal applied to the element inducing mode-locking. From measurements of the tuning rate for different modulation frequency values of the driving signal, the effective dispersion in the cavity can be obtained. With the knowledge of the dispersion, important parameters of the swept source can be inferred in terms of tuning ans its coherence properties. Such parameters determine essential characteristics of the SS-OCT system that depend on the source parameters.

2. Methods

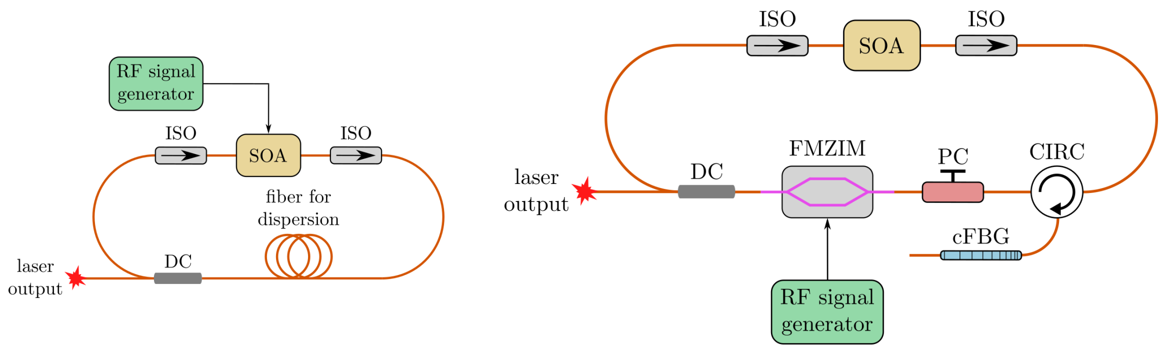

Fig. 1. Left: dispersive cavity using direct RF modulation of the gain as a mode-locking mechanism. Right: dispersive cavity σ-configuration using intensity modulation as the mode-locking mechanism. SOA - semiconductor optical amplifier, ISO - optical isolator, DC - directional coupler, CIRC - optical circulator, PC - polarization controller, FMZIM - fibre Mach-Zehnder intensity modulator.

The wavelength tuning range $\Delta\lambda$ in dispersive cavity mode-locked set-ups in Fig. 1 is linearly proportional to the change in the modulation frequency Δf_m of the RF signal being applied to the mode-locking element [3] (either the SOA or the FMZIM respectively in Fig. 1 right and Fig. left)

$$\Delta\lambda = -S(\overline{D}, f_m)\Delta f_m = -\frac{\overline{n}}{c\overline{D} f_m}\Delta f_m. \tag{1}$$

where $\overline{n}$ and $\overline{D}$ [s/m^2] are the average index of refraction in the cavity and effective dispersion coefficient in the cavity, respectively. In the technique presented, it is assumed that dispersion in the cavity varies only slightly with wavelength λ. The proportional constant $S(\overline{D}, f_m)$ in (1) represents the so called wavelength tuning sensitivity. The method presented relies on the calculation of $\overline{D}$ from the slope K of the linear regression of measurements of tuning rate $\Delta\lambda/\Delta f_m$ against Δf_m [4]

$$\frac{\Delta\lambda}{\Delta f_m} = \frac{K}{f_m}, \text{ where } K = -\frac{\overline{n}}{c\overline{D}}. \tag{2}$$

3. Results

To explore usability and potential limitations of the technique, the assessment of the dispersion in a cavity consisting of SMF-28e fibre only was first performed. The set-up for measuring the dispersion of the fibre is depicted in Fig.

1left. The contributions of the non-fibre parts, such as the gain medium for example, to the dispersion in the cavity could be neglected considering their relative short lengths. Dispersion measurements for three spools of SMF-28e fibre of different lengths inserted in the cavity are performed. The results are displayed in Fig. 2, where L_{cav} labels the net cavity length, and compared to the already known values of the dispersion [5]. In all cases, the comparison with theoretical values show differences below 1 ps/(nm · km).

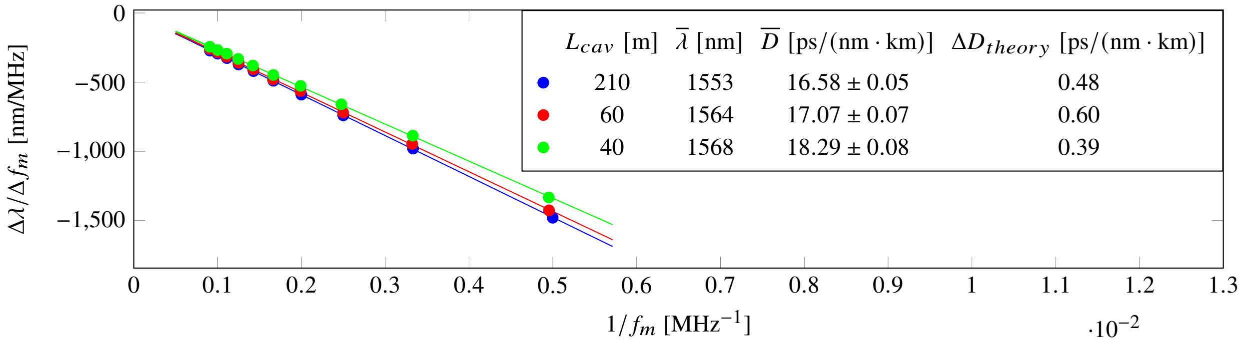

Fig. 2. Dispersion assessments for all SMF-28e fibre lengths measured in the cavity in Fig. 1 left.

With the same technique, it was also possible to measure the effective dispersion of the cavity in Fig. 1 right including all its optical elements as well as polarization maintaining leads of the intensity modulator and the dispersion of the employed cFBG. The results are displayed in Fig. 3 where effective time delay dispersions $\overline{\mathrm{TDD}} = \overline{D}L_{cav}$ are extracted.

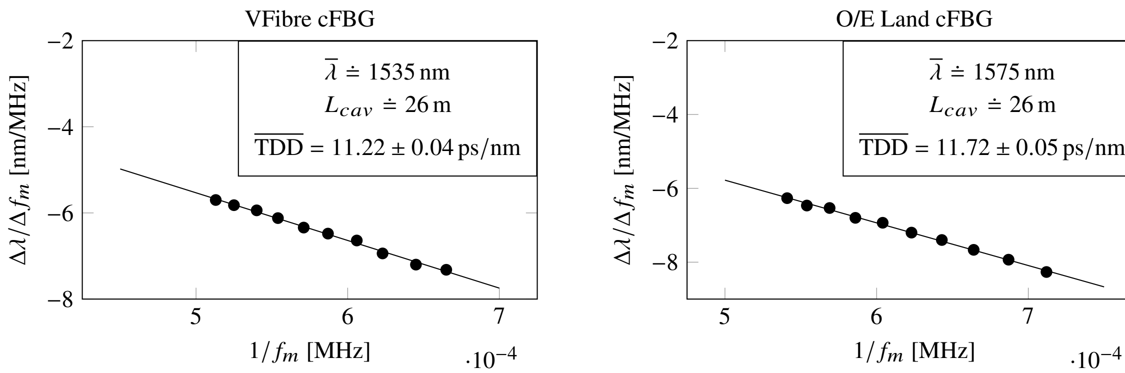

Fig. 3. Tuning rate $\Delta\lambda/\Delta f_m$ measurements in the cavity Fig. 1 right with two different cFBGs.

4. Conclusion

A simple dispersion assessment technique is demonstrated tha exhibits good accuracy. Its main advantage is that it employs the same elements to be used in a configuration of the swept source for SS-OCT. The method is under continuous research to improve its accuracy and consider contribution of sting of various optical parts.

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