Limitations in Length Matching Between Optical Channels in Fiber-based CBC Systems

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Introduction

Coherent Beam Combining (CBC) arouses great interest in the laser industry because it makes it possible to obtain a **laser beam** with a **much higher power** than is possible with a single source, and with high beam quality.

There are many methods for implementing coherent combining. In the MOPA (Master Oscillator Power Amplifier) configuration, a single laser source splits into several channels, each of which is optically amplified by an optical amplifier, and the beams are then recombined.

Coherent combining of the laser beams requires, among other things, precise matching of the channel lengths. For high power systems, with power > several-100 watts per channel, the precision must be less than 1mm. Optical path differences (OPD) between the channels arise during the operation of the laser due to a variety of phenomena. They require a system response in order to maintain the synchronization between the phases.

In this work two main factors that impact the coordination of fiber-based CBC amplifier channel lengths were examined: (1) variations in ambient temperature and (2) variations in channel power. The effect of these factors was calculated theoretically and measured experimentally. The results of the measurements stand in good agreement with the theory.

Background

- Laser systems based on CBC require precise matching of the channel lengths.

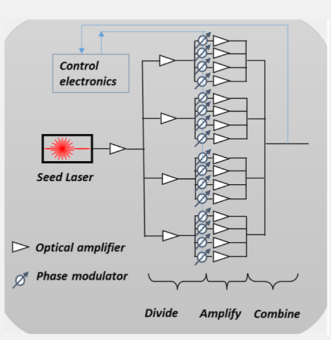

Figure 1: Schematic CBC Laser System in MOPA Configuration

- OPD's between the channels arise during laser operation due to fluctuations in the fibers' **ambient temperature** and elevated **amplifier power**. The latter affects the system through pump-induced refractive index change [1] and by the internal thermal effect caused by the quantum defect [2].

Objectives

- Measure the change in the optical path length (OPL) due to ambient temperature of different fused-silica fibers.
- Measure the OPL change as a function of the amplifier output power.

Method

- The change in the fibers' OPL was measured using a Mach-Zehnder interferometer. Two different methods, shown in Figure 2, were employed:

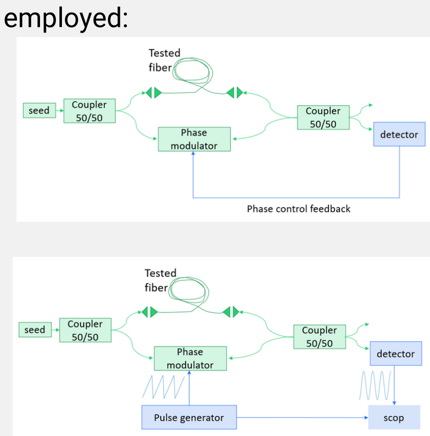

Figure 2: OPL Measurement Systems: Phase-locking Method (top) and Sawtooth-wave Method (bottom) .

Results

The OPL change due to **ambient temperature** of four fused-silica fibers was measured by heating the fibers to temperatures in the range 25-61°C. The results are shown in Figure 3:

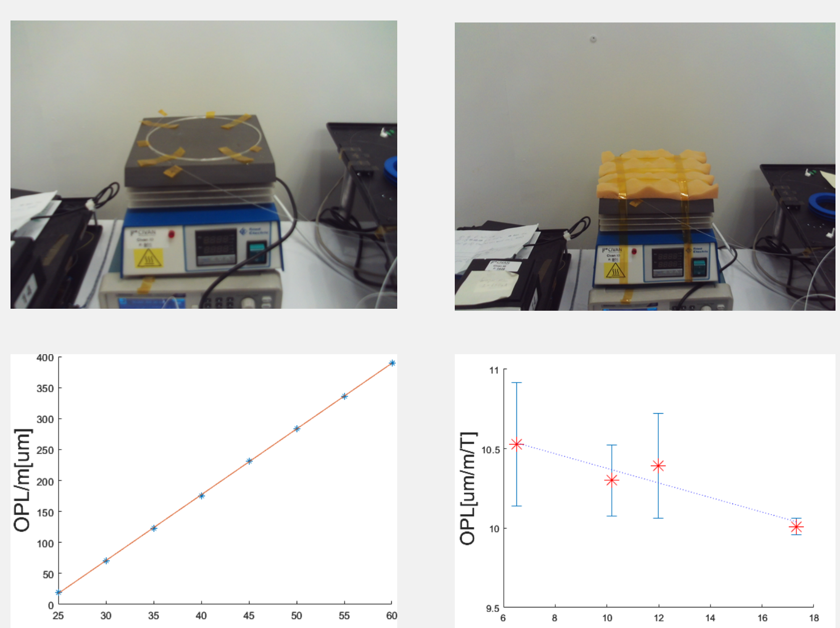

Figure 3: OPL Change Due to Ambient Temperature of Four Fused-silica Fibers

(a)- The tested fiber is attached to the hot plate and isolated from the ambient air temperature (top)

(b) - Linearity of OPL change due temperature (bottom left)

(c) - The dependence of the effect on the fiber mode diameter for four fiber types (bottom right)

The OPL increase as a function of **amplifier power** was measured. The results are shown in Figure 4:

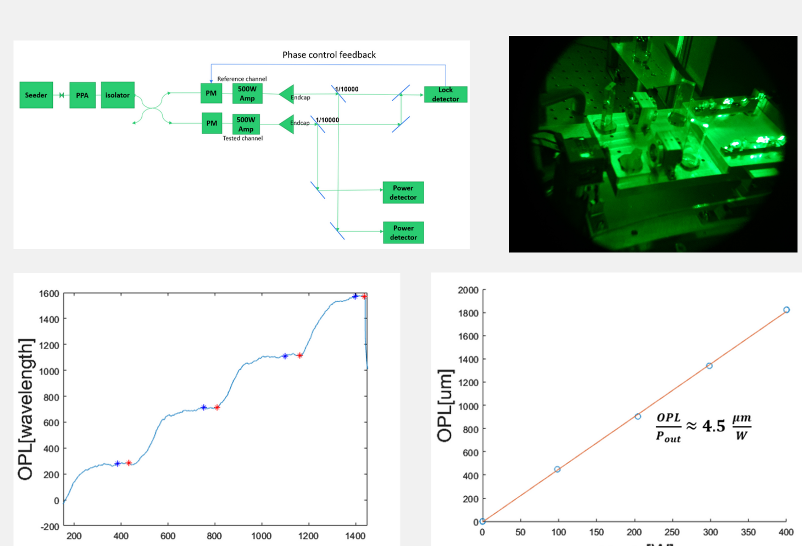

Figure 4: OPL Change as a Function of the Amplifier Output Power.

(a) - The experimental system (top)

(b) - The OPL change during the measurement (bottom left)

(c) - Linearity of the OPL change with the output power (bottom right)

Discussion

The OPL change due to ambient temperature of four fused-silica fibers in the range of 25°C – 61°C was measured. The results lie in the range 10-10.5ppm/°C. There appears to be a correlation with the mode diameter of the fiber.

The theoretical value of the OPL change is due to both the thermal properties of fused silica (9.4ppm/°C [3][4]) and the geometrical structure of the fiber [5]. The latter factor could explain the measured dependence on the fiber mode diameter.

The effect of the amplifier output power on the OPL was measured and calculated. The results are summarized in the table below.

	Measured	Theoretical		
		Kramer Kronig	Quantum defect	Both phenomena
OPD/power[$\mu m/W$]	**4.5**	3	1	**4**

The measured value closely matches the theoretical.

The changes in ambient temperature and amplifier power could create OPD's between channels on the order of mm's . This could be significant for the efficiency in combining channels.

Summary & Conclusions

- The optical path dependency on the ambient temperature and on the amplifier output power was measured and calculated theoretically.
- The measured values show good agreement with the theoretical values.
- The results display a significant increase of the optical path length arising from these phenomena. This would likely affect length matching. Thus these phenomena should be taken into account when designing a laser system of this type.

References

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