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# Simultaneous Oscillation of Wavelength-Tunable Singlemode Lasers Using Er :ZBLALiP Whispering Gallery Mode Resonator

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**Abstract :** The coupling by two half tapers on the same micro-spherical resonator in Er:ZBLALiP allows two independent single mode laser emissions to be obtained simultaneously. We study the emission characteristics and the resulting beat note signal.

OCIS code: 140.3410 Laser resonators, 350.4010 Microwaves

## 1. Introduction

Micro spherical resonators have attracted significant attention in recent years due to their interesting optical properties and the range of applications for which they can be used [1-3]. Most of the publications dedicated to micro spherical laser are devoted to lasing effects in different materials where the spectral properties of the emission depends on (i) the choice of dopant (e.g. Er<sup>3+</sup>, Yb<sup>3+</sup>, Tm<sup>3+</sup>) and (ii) the host matrix (e.g. silica, fluoride, phosphate or telluride glass) in which the dopant is embedded. This paper is more dedicated to a potential application of the WGM micro resonators to obtain a dual wavelength laser source. We use as active medium Er<sup>3+</sup> doped fluoride ZBLALiP glass [4]. This glass is well adapted to the development of micro spherical laser operating in the infrared region, in particular with emission wavelengths falling in the C-band [5-7].

## 2. Experiments and results

Our experiments are focused on the optical transition  $^4I_{13/2} \rightarrow ^4I_{15/2}$  and among the different pumping wavelengths which can be used (810 nm, 975 nm and 1480 nm) [8] we chose 1480 nm in order to obtain a good overlap between the pump and laser whispering gallery mode volumes. This overlap is also favorable for improving the coupling of the pump light from a tapered fiber while preserving efficient collection of the laser light out of the sphere into the same fiber. The resonator is coupled with two half-tapered fibers (inset of Fig.1). For each of them the gap ( $e_i$ ) and the position ( $\ell_i$ ) between the half-taper and the sphere were controlled by a 3-axis micro-translation stage. The first (numbered as 1# half taper) is characterized by a drawn length  $L=227 \mu\text{m}$  and a taper end reduced to  $\phi=2.8 \mu\text{m}$  in diameter. The second (2# half taper) is characterized by  $L=210 \mu\text{m}$  and  $\phi=2.8 \mu\text{m}$ . The matching of the effective refractive index of the mode guided in the taper and of the sphere's best WGM depends on the wavelength [9]. Consequently this kind of coupler allows the emitted wavelength to be selected and each taper can be considered as a wavelength tunable input/output coupler by varying the position ( $\ell_i$ ) and the gap ( $e_i$ ) between the sphere and the taper.

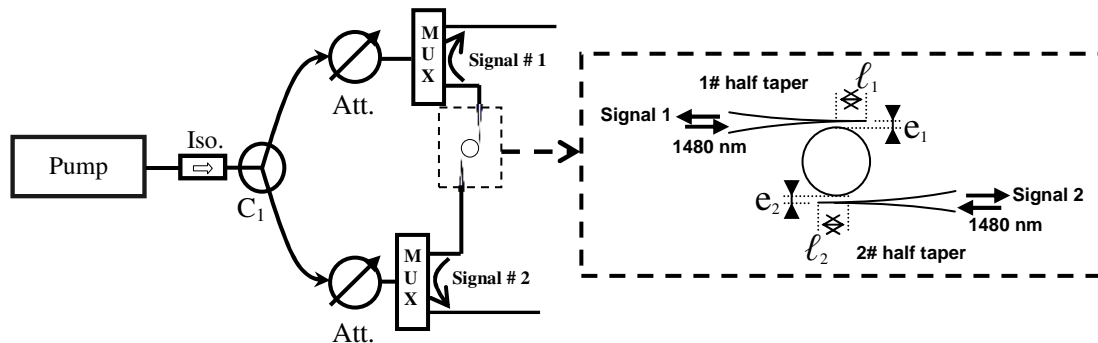


Fig.1. Experimental setup of double wavelength dual half taper coupled Whispering Gallery Modes Laser.

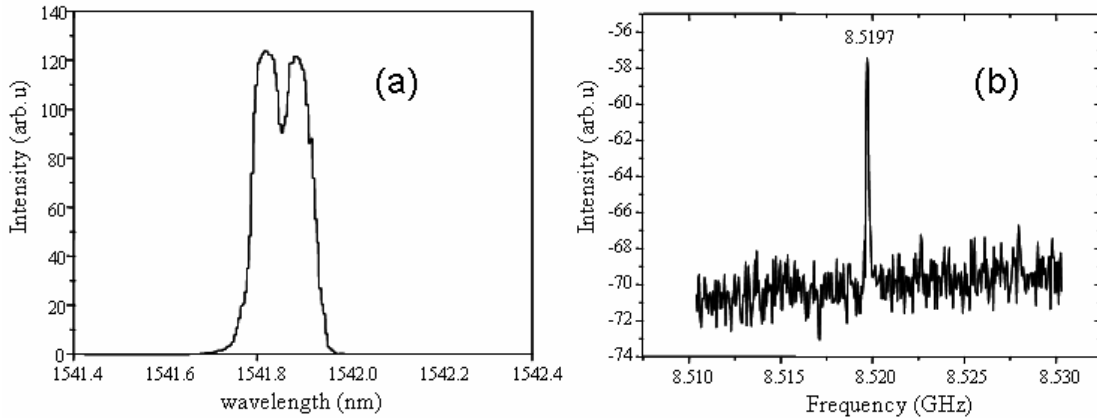


Fig.2. (a) Optical spectrum of the superposition of laser signals #1 and #2; (b) beat note signal observe on an electric spectrum analyzer.

Figure 1 shows the schematic diagram of our experimental setup. The laser pumping source is constituted of a laser diode at 1480 nm emitting a maximum power of 175 mW. We use a 3-dB coupler ( $C_1$ ) to divide the pump source in two equivalent ways. Each input/output coupler is connected with a variable attenuator (in order to pump separately the micro-sphere by the two half-tapers), and a 1480/1550nm wavelength division multiplexer (MUX). The wavelength division multiplexer allows the emitted signal (fluorescence or laser signal) to be pumped and collected through the same fibre then to be separated. For each channel, the use of 90/10 coupler (not reported on figure) allows the WGM emissions to be monitored simultaneously by a 0.07-nm-resolution optical spectrum analyzer (OSA) via the ten percent outputs. The 90 percent outputs are used to analyse the laser emissions. The single or multimode emission is characterized with a high resolution Fabry-Pérot. The intensity fluctuations of whispering gallery mode laser lines were measured with low noise detection. A finer spectral analysis can be achieved with a delayed self heterodyne detection of the optical signal followed by a study of the beating electrical signal [10, 11]. In a first set of experiments we tuned the input/output couplers to obtain laser emissions and identified, for each channel, the pump range leading to single mode emission. In a second set of experiments, by varying independently the pump intensity for each channel we measured the characteristics in intensity and line width for each signal #i just above the threshold. These measurements demonstrated how these two signals were independent versus the independent variation of the pump intensities. The spectral distance between the two emissions can be tuned by varying the parameters ( $\ell_1, e_1, \ell_2, e_2$ ). This distance runs from tens of nanometres to few GHz. Figure 2-(a) shows an optical spectrum of the superimposed laser-light sources measured with a 0.07 nm resolution optical spectrum analyzer. Figure 2-(b) presents the beat note signal at 8.52 GHz corresponding to the dual wavelength optical signal.

### 3. Conclusion

One WGM micro resonator was used to create lasing cavities for two lasing lights simultaneously. Emissions were single-mode, narrow linewidth (<100 kHz) and wavelength tunable. These results correspond to preliminary works on frequency-superimposed laser-light sources.

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