Mid-Infrared Fiber Lasers

Réal Vallée, Martin Bernier, Vincent Fortin, Yigit Ozan Aydin, Pascal Paradis, Frédéric Jobin, Simon Duval, Frédéric Maes

Center for Optics, Photonics and Lasers, Laval University, Quebec, G1V0A6, Canada

Abstract.

Continuous wave and pulsed laser emission between 2.7 and 4.0 μm from Er^{+3}, Ho^{+3} or Dy^{+3} doped fluorozirconate (ZrF_4) glass fiber lasers is reported. A survey is presented of the most significant progress achieved recently in terms of average and peak powers as well as pulse energy.

Keywords: fiber lasers, mid-IR coherent radiation, fiber components
*rvallee@copl.ulaval.ca;

Introduction

Fluoride glass optical fibers have emerged over the last two decades as the most serious contender to address the challenges related to the development of longer wavelength fiber lasers, more specifically between 2.7 and 4.0 μm. As low-phonon energy glasses alleviating multi-phonon decay, both zirconium fluoride (ZrF_4) and indium fluoride (InF_3) single-mode optical fibers are now available commercially with minimum losses of 10dB/km or less, with double-clad geometries and with lanthanide concentrations approaching 10 mol%. Also, fluoride fiber optical components including Fiber Bragg gratings or pump combiners are now also available thus allowing for the development of rugged monolithic Mid-IR fiber lasers.

II Presentation overview

1. High power cw emission

Until recently, the general trend for the maximum output power from mid-infrared fiber lasers as a function of wavelength was following a steady exponential decrease, as shown on Figure 1 (dashed line). According to this trend, watt-level operation was only achieved near 3 μm from Er^{3+} doped ZrF_4 fibers. In fact, Er^{3+}/ZrF_4 fiber laser used to be the most mature one over the mid-IR region. Over the last few years, developments involving both Ho^{3+} and Dy^{3+} ions (along with Er^{3+}) have led to significant improvements of mid-IR fiber lasers in terms of both their maximum cw output power and overall spectral coverage[1-3] (stars).

Nowadays, watt-level operation is possible over almost the entire spectral region between 2.7 and 4.0 μm and the recent availability of low loss InF_3 fibers is holding promises of further improvements at longer wavelength. Fluoride glass optical fibers have thus dissipated the general apprehension regarding their high power handling ability although a fiber tip photo-degradation issue, especially in the neighborhood of the O-H resonance peak, was reported as a possible hurdle to their power scaling.

2. Pulsed laser operation

Several mid-IR applications cannot be addressed with cw FLs and are calling for their pulsed counterparts. Accordingly, several pulsed regimes of operation of mid-IR FLs were recently investigated. Both Q-switched and gain-switched FLs were demonstrated, leading to pulsed operation in the ns regime near both 3.0 and 3.5 μm. Pulse energies approaching the 100 μJ
level with an average power exceeding 10 W were namely produced from a rugged monolithic cavity operating at 2825 nm[4]. Pulse energies in excess of 100 μJ were also produced in the sub-nanosecond regime based on an Ho^{+3}-doped fiber based

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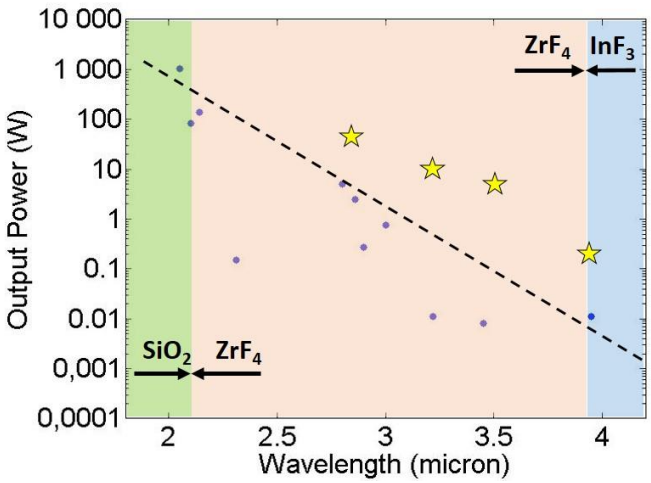

Figure 1. Maximum output power from cw mid-IR fiber lasers as a function of wavelength.

amplifier scheme. The femtosecond regime was also studied via a fiber based ring laser cavity relying on the nonlinear polarization evolution mode-locked scheme and 207 fs pulses with 3.5 kW peak power near 2.8 μm were produced[5]. Such femtosecond FL was further used as a seed for an Er^{+3}-doped-fiber amplifier, resulting (via the soliton self-frequency shift process) in a watt level femtosecond fiber source tunable from 2.8 to 3.6 μm.

III Conclusion

Significant progresses were recently reported for both cw and pulsed mid-IR fiber lasers so that these sources can now address a growing number of applications that are specific to this spectral region. Further progress is also expected to occur in the near future in terms of both average power scaling (up to 100W) and wavelength coverage (up to 4 μm).

IV References

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