

Title: Tunable Laser Development for In-flight Fiber Optic Based Structural Health Monitoring Systems

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Objective: The objective of this task is to investigate, develop, and demonstrate a low-cost swept lasing light source for NASA DFRC's fiber optics sensing system (FOSS) to perform structural health monitoring on current and future aerospace vehicles.

Background: Fiber optics sensors offer tremendous safety advantages over their conventional counterparts. These sensors are chemically inert, immune to electromagnetic interference or electromagnetic pulses (EMI/EMP), and are not susceptible to sparking or Joule heating. Thousands of Fiber Bragg Gratings (FBG) sensor arrays, placed within a single hair-like fiber, can measure environmental perturbation such as temperature and strain using NASA-developed Optical Frequency Domain Reflectometry (OFDR). OFDR allows for measurement maps with very high spatial resolution with spatial fidelities that approach computational models. Highly resolved full-field strain and temperature mapping provides a more thorough assessment of damage and the onset of catastrophic failure, which has potential to save lives and enhance vehicle safety.

Currently one of the most important components inside the FOSS system is the tunable swept laser light source that is used to interact with thousands of Fiber Bragg Grating (FBG) sensors. As FOSS technology matures from laboratory-based equipment to a flight-tested system, the performance of the laser swept source has increasingly become the bottleneck of the system. Existing tunable swept laser being deployed into FOSS is based upon bulk-optics that involves moving mirrors to tune the laser, therefore the packaging size and the tuning speed of the laser is mechanically limited. The moving mirror element of the laser is also a deterrent to developing a ruggedized system suitable for high G-force such as a fighter jet or a rock launch. Another deterrent of the current technology is the footprint of the laser composed of a substantial amount of the overall system size. Therefore development of a compact, ruggedized swept lasing source may lead to deployment of said system onto other NASA spacecraft and aerospace vehicles.

Technical Approach: From thorough research through state-of-the-art laser development literature, an all-fiber-based swept ring laser based on current telecommunication technology will be developed. An all-fiber Fabry-Perot tunable filter driven by piezoelectric disk will be the tuning source of the laser, while erbium-doped fiber excited by a pump laser will be the lasing source of the laser. A prototype swept laser will be built and tested to compare with the existing deployed laser to measure the laser output power, linewidth of the laser, the laser swept wavelength range and the swept speed of the laser. If the prototype laser is comparable to the current laser, the prototype will replace the current laser as a lasing source on an existing FOSS to conduct strain measurement using FBG strain testing coupon. The resultant strain measurement will be compared with existing FOSS for accuracy, consistency, repeatability, and reliability.

Customers: This work directly supports the NASA Launch Services Program, which has identified NASA Dryden's FOSS as an enabling technology to address concerns related to specific missions or fleet of launch vehicles.

Metrics: Publications and test reports outlining results, procedures and progress.

Products: Finding will also be compiled and presented/published at various conferences and/or conference proceedings and sent to the appropriate authorities at NASA.

Schedule/Milestones:

- Conduct literature search on tunable swept laser technology (Fall 2010)
- Acquire necessary materials and components to develop all-fiber-based swept laser. (Spring 2011)
- Determine that using erbium-doped fiber amplifier (EDFA) is more suitable as a lasing source for the prototype laser compare to a semiconductor optical amplifier (SOA) (Winter 2011)
- Develop a working prototype of a swept laser with suitable power to lase, and is able to swept across the C-band, from 1530 to 1565 nm (Spring 2012)
- Improve the performance of the prototype laser to be comparable to the existing laser, specifically to be able to lase in single mode with no mode hopping (2013)
- Conduct FOSS measurement with the prototype laser and verify results (2014)

Status and Accomplishments during this period:

- Currently the fiber ring laser is different from existing external cavity laser (ECL) due to
 - Laser is lasing in multi-mode instead of single mode because of longer cavity length compared to ECL (tenths of meter in ring laser vs couple of mm in ECL)

- Laser linewidth of ring laser is currently limited by the linewidth of the FP tunable filter
 - There is a trade-off between how narrow the linewidth of FP filter one can endure vs amount of power generated from EDFA, which results in permanently damaging the filter
 - Some FFP-TFs were damaged due to high initial power
- However, these issues can be overcome
 - By various techniques stated in literature, single-longitudinal mode laser with narrow linewidth can be generated in fiber ring laser
 - Vernier Loop Effect, to limit mode competition
 - Saturable Absorber in un-doped Erbium doped fiber,

Key Facilities

- DFRC Flight Loads Laboratory
- AERO Institute

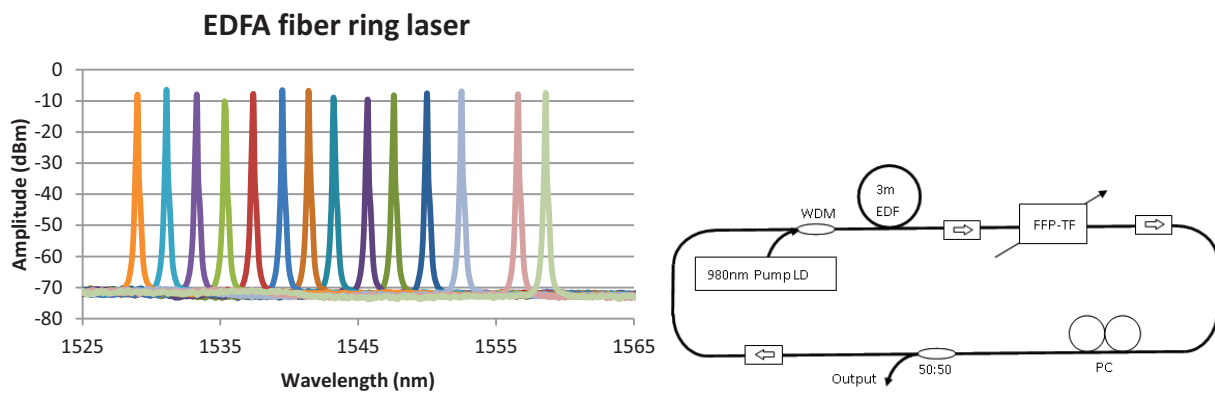


Figure 1. Current EDFA-based fiber ring laser output and schematics.

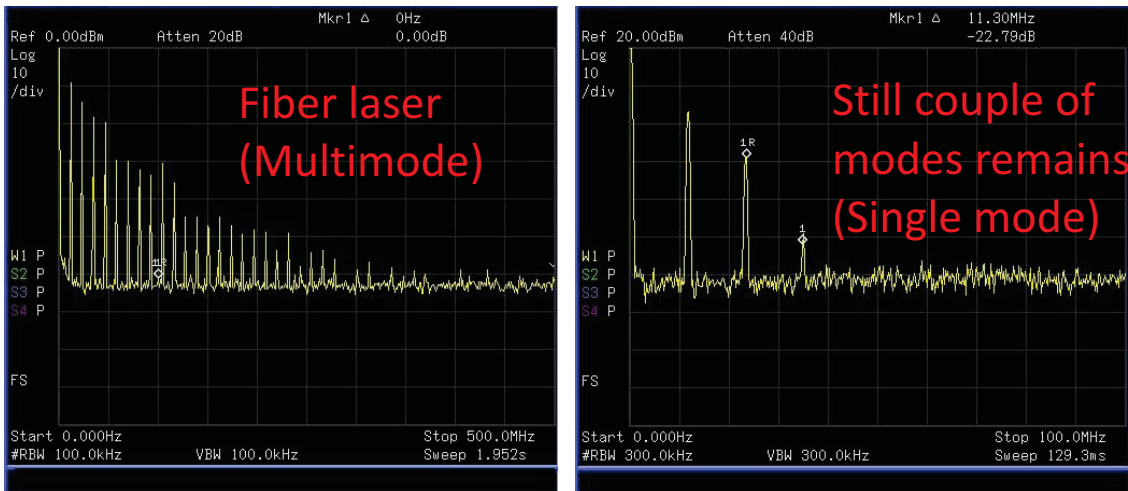


Figure 2. Self-homodyne detection of laser output from spectrum analyzer showing currently the prototype fiber laser exhibits in the multimode regime, while progress is being made to reduce the response to a single longitudinal mode.