NP Photonics, Inc • UA Science and Technology Park • 9030
S. Rita Road, Suite 120 • Tucson, Arizona 85747
Tel: (520) 799-7400 • Fax: (520) 799-7403

Single Frequency Fiber Lasers for Defense, Security and Military Applications

Features of NP's Fiber Lasers

Key features of NP's 1.55 µm fiber laser are the ultra narrow linewidth of 2 kHz and excellent frequency stability of better than 10 MHz over hours, resulting in an extremely long coherence length and low phase noise, about two orders of magnitude lower than the best DFB laser. This fiber laser features an output power of 150 mW, a side mode suppression ration of greater than 50dB, a thermal tuning range of 20 GHz, aa well as a continuous and linear piezo tuning range of about 50 MHz/V.

In addition to the fiber laser at 1.55µm, the most eye-safe wavelength, NP Photonics has developed 1 µm fiber lasers exhibiting similar laser characteristics, and is ready to extend the laser wavelength to 2µm and beyond. Further, NP's new, novel Q-switched all-fiber laser allows the generation of single-frequency, nanosecond pulses at wavelengths including 1.55 µm as well as 1 µm.

NP's Core Technology

The laser cavity of NP's fiber laser is established by two spectrally narrow passive fiber Bragg gratings (FBG) that are fusion spliced to a very short piece of active material, as depicted in Figure 1. This design takes advantage of NP's proprietary, highly Yb/Er co-doped fiber allowing the total length of the fiber laser cavity to be less than 5 cm – a task impossible with conventional fiber approaches. Such a short cavity length is uniquely suited for extremely stable and mode hop free single frequency operation. The spectral linewidth of these lasers is typically on the order of 2 kHz and the emission is linearly polarized. Compact and the high reliable fiber lasers can be readily built with such a short cavity.

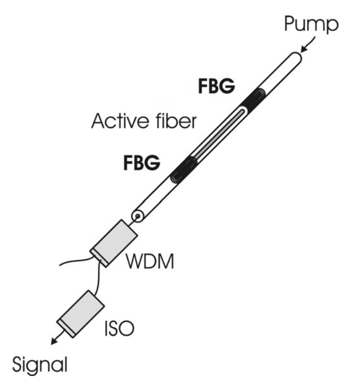

Figure 1 Schematic of the laser

NP designs and manufactures glasses and fibers in house. The unique active fiber technology enables us to outperform competitors in fiber lasers. NP's core technology is created by the dedicated work of more than 20 PhDs in our design and technology teams developing new glass compositions, new fiber structures, and new photonics devices. Our facility includes glass fabrication lab, preform fabrication lab, fiber drawing tower, fiber characterization lab, fiber devices environment test lab, electronic design and fabrication lab, photolithographic process lab, laser characterization and measurement lab, as well as Class 100, 1,000 and 10,000 clean rooms including assembly/production facility.

Defense, Security and Military Applications

NP's fiber lasers enable many applications in defense, security and military, especially where long coherence length, or low phase noise light source is needed. The following highlights a few examples.

1. Distributed Fiber Optical Sensor For Security

NP's narrow linewidth fiber laser can be used to build distributed fiber optical sensor systems to detect, locate, and classify disturbances over a length of greater than 10-km using a frequency modulated continuous wave (FMCW) technique, providing cost-effective security systems for nuclear power plants, oil and gas pipeline integrity, military bases, and national borders. In FMCW technique, the optical frequency of the laser source is modulated around its center frequency whereas part of the light is coupled into a reference arm with fixed reflection, which plays the role of the local oscillator (LO) in a heterodyne coherent detection scheme. A second (long) optical fiber is used as the sensing element as depicted in Figure 2. The reflected laser from the sensing fiber is mixed with the light from the local oscillator generating a beat frequency, which is proportional to the difference time delay it experiences. The distance information of the sensing fiber is obtained by measuring the photocurrent beat frequency using an electrical spectrum analyzer. The distributed reflection of the sensing fiber can in the simplest case just be Rayleigh backscattering of the optical fiber. Sensitivities down to –100 dB can be easily achieved. In coherent detection schemes, a large dynamic measurement range can be obtained since the photocurrent beat signal is proportional to the square root of the returned laser

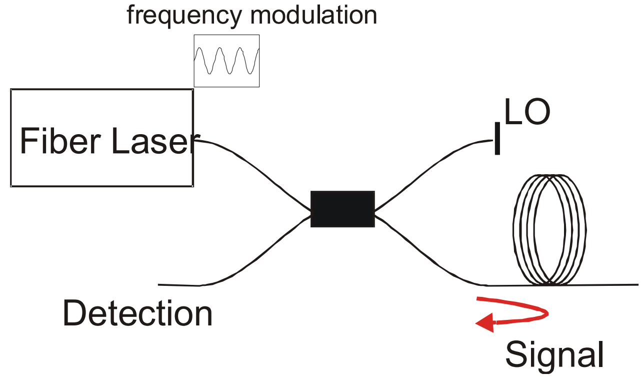

Figure 2. Schematic of FMCW technique

power and light from the local oscillator can be used to amplify the backscattered signal. Changes of the returned laser caused by any form of disturbance to the optical fiber, be it pressure, temperature, acoustic, or vibration can be detected.

The most critical element for any coherent FMCW technique is a long coherence length light source to achieve high spatial resolution and a large measurement range. NP's narrow linewidth fiber laser exhibits an extremely long coherence length due to its narrow linewidth, lending itself as an ideal light source for the FMCW technique. With NP's fiber laser, the maximum range can be extended to greater than 10-km as opposed to hundreds meters demonstrated with a DFB laser diode. Due to the ability to monitor very long distributed sensor with a single laser and a photodetector, such a sensor system could provide enhanced security in a cost effective manner for a large area or a long length of interest for homeland security and military.

2. Laser Designator/Rangefinder for Military Intelligence, Surveillance, and Reconnaissance

Current military intelligence, surveillance and reconnaissance (ISR) platforms are usually equipped with electro-optic imaging systems, which generally have very long range imaging performance, and can accurately locate small mobile targets such as transporter erector launchers and tanks. However, the ability of these systems to pass the actual location of these targets to strike platforms that deliver and direct a weapon to the target is limited due to geo-location accuracy of the imaging system. There is a great need for a low-cost very long-distance (several hundreds kilometers) laser designator/rangefinder with good accuracy (1 meter or less) for the ISR missions.

The longest distance that can be measured with most of compact commercial laser rangefinders is about 10~20 kilometers, due to limitations of dynamic range and sensitivity of the measurements. This is not long enough for the ISR mission. Most of current commercial laser rangefinders, especially for long distance measurement, are based on optical time-domain reflectometry with pulsed lasers. These systems directly probe back-reflected optical pulse signal from a target with a fast photodetector and simple analyzing implements. The measurement accuracy, usually about 1~10 meters, is determined by the pulse width of the radiation (corresponding to 3~30 nanoseconds long laser pulses). The accuracy is better as the pulses are made shorter, at the same time the measurement bandwidth needs to be increased. This raises the noise levels detected, and so reduces the dynamic range of the system. Since the photocurrent signal is linearly proportional to the power of back-reflected optical signal incident on the detector for direct detection, the detector noise floor limits signal sensitivity. Thus the longest distance that can be measured with most of compact commercial laser rangefinders is about 10~20 kilometers.

NP's 1.55-µm narrow linewidth fiber lasers can be used to build long-range, several hundreds kilometers, laser designator/rangefinder for ISR using coherent frequency-modulated continuous-wave (FMCW) reflectometry technique. The long-range laser designator/rangefinder, as depicted in Figure 3, consists of a laser source, collimator & receiver, and signal analyzer. The frequency of the narrow linewidth fiber laser is linearly modulated rapidly. The distance information is obtained by measuring the photocurrent beat frequency between a reference signal and the back-reflected signal from a target. Linewidth or coherence length of the laser determines measurement range and sensitivity in FMCW reflectometry. The NP fiber laser has extremely narrow linewidth of less than 2 kHz, 2~3 orders of magnitude narrower than the best semiconductor laser. This feature gives the laser potential to achieve several hundred kilometers rangefindering with accuracy of 1 meter or less.

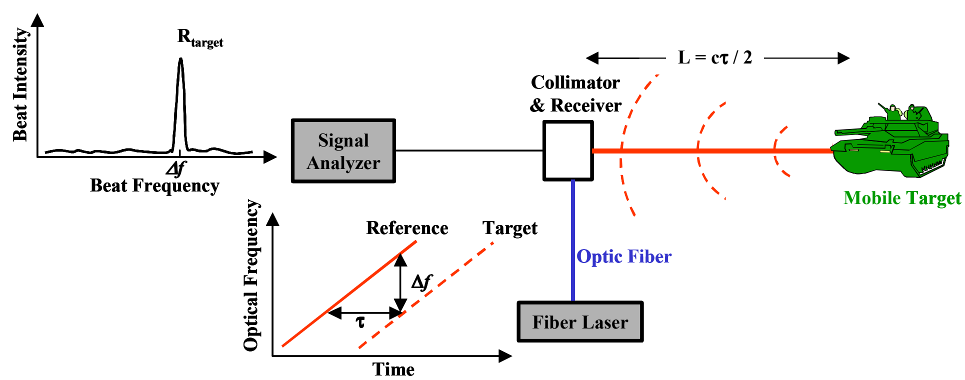

Figure 3. Graphic illustration for the FMCW laser rangefinder

Such a designator/rangefinder offers numerous advantages over most commercial laser rangefinders based on pulsed lasers, including very high dynamic range and sensitivity, eye-safety, compactness, ruggedness, and mounting flexibility.

3. Fiber Optic Hydrophone Sonar Array

Fiber optic hydrophone sonar arrays based upon interferometric fiber optic sensor offer many advantages over conventional electroceramic based hydrophones as they are electrically passive, immune to electromagnetic interference, feature reduced weight and cross section of cables, and reduced through-life cost. Such systems have been an area of active research for the last two decades for a range of military applications. Military is developing seabed hydrophone arrays, fiber optic bottom mounted arrays, as well as towed arrays using a combination of time and wavelength division multiplexing (TDM/WDM) to achieve high channel counts.

NP's fiber laser is the ideal laser source for this application since it exhibits extremely low phase noise, low relative intensity noise (RIN), excellent acoustic insensitivity, and high output power without using amplifiers. In an interferometric fiber sensor both RIN and frequency noise can degrade the phase resolution, which determines the pressure resolution of hydrophones. The frequency noise is converted to phase noise by the interferometer and is proportional to the path imbalance in the interferometer. The frequency noise of NP's fiber laser was measured to be two orders of magnitude lower than the best DFB lasers, which are used in many systems. The high output power without using amplifiers eliminates all spontaneously induced noise.

Such a system can also be employed for undersea oil exploration or earthquake detection.

4. Doppler LIDAR for Unmanned/Aerial/Ground Vehicles

In general, coherent lidar systems require a pulsed laser source that operates in single frequency in order to generate a heterodyne- or homodyne-signal for Doppler sensing. Conventionally, such lasers are constructed using a slave laser, which is a powerful pulsed laser oscillator, and a master laser, which is a low-power, continuous-wave, stable laser and a complex control method to enforce and maintain the slave laser to oscillate in a single-frequency. Such lasers are usually large in size and significant challenge exists in ruggedizing the entire unit, because it involves sensitive free-space optical alignments not just in the laser resonators themselves, but also in coupling the seed signal from the master laser to the slave laser.

Ultra compact Doppler LIDAR can be built using NP's single-frequency, all-fiber Q-switched pulsed laser. The pulse laser can either be free-running with another local oscillator laser passively or actively locked in frequency to the pulsed laser, or it can be injection-seeded by the local oscillator laser. The Doppler-shift of the returned signal can be measured simply by the beat frequency with the reference beam from the local oscillator and the returned signal. NP's continuous-wave fiber lasers are ideal seed laser, and provides excellent compatibility with NP's all-fiber Q-switched laser. All devices can be packaged into a small and lightweight box. Fiber lasers are free of alignment error, owing to their guided wave nature. This is particularly pronounced in all-fiber laser sources. The 1.55 μm range, the most eye-safe range, is not accessible from crystalline solid-state lasers known to date, except for ones involving complex nonlinear frequency down conversion processes. This makes such erbium-doped fiber lasers attractive as the laser source that needs to be emitted into the public air.

5. Airborne Laser Radar

By using NP Photonics' proprietary highly doped phosphate optical glass fibers, the laser cavity can be short, allowing the generation of short pulses which is an important feature for lasers for laser radar applications. Using a novel, patent-pending, yet simple and unique technique, NP has demonstrated a compact all-fiber Q-switched laser that generates short (5-20 ns) pulses with an average power of 44 mW at a repetition rate of 100 kHz at 1.55 µm. An amplifier can boost the average power of the fiber laser to levels of 5 to 10 W. A fiber laser operating at 1.06 or 1.5 µm nominal wavelength, pulse repetition rates of 20-30 kHz, individual pulse energy of 0.3-1.0 mJ, pulse widths of 5-20 ns, peak power near 25-100 kW, and average laser output power of 5-10 W can be use to replace current solid state laser for airborne laser radar. Pulsed lasers at 1.5 µm, in particular, ar not available e from transitions in crystalline laser materials or gas lasers.

The major challenge for current solid-state laser is to maintain the optical alignment of the laser cavity, including all the components within. Absence of robust, rugged, high-performance lasers has limited the wide deployment of solid-state lasers to scientific labs or industrial application in a controlled environment. Fiber lasers have numerous advantages including high efficiency and robustness requiring no free-space alignment. However, there remain very high hurdles to overcome for the fiber laser before completely replacing the solid-state lasers. One such hurdle is to obtain high-peak powers by Q-switching. Many industrial as well as sensing/military application require short pulses of the order of nanoseconds to a few tens of nanoseconds with relatively large (compared to mode-locked lasers) pulse energies. Short-pulse fiber lasers are available in a mode-locked format with typical pulsewidth down to the subpicosecond regime; however, their pulse energies are limited to nanojoules, severely limiting the peak power. Due to the lack of proper Q-switching devices, Q-switched fiber lasers were either poor performing, or loose the advantages of the fiber cavity by adding a free space optical component. Our patent pending Q-switch technique enables us to develop high peak power fiber laser for eye-safe airborne laser radar.

Contact: *Should you have any questions or need more detailed information, please contact Shibin Jiang, Ph.D., Senior Vice President, Technology, at 520-799-7407 (Phone) or send e-mail at Jiang@npphotonics.com.*