Fiber Lasers

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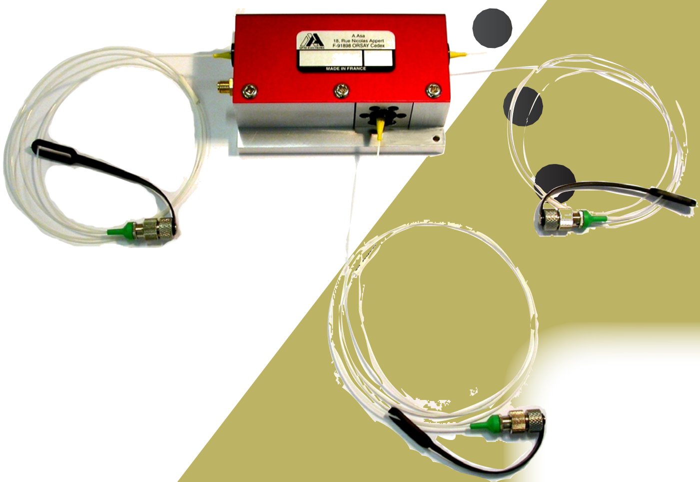
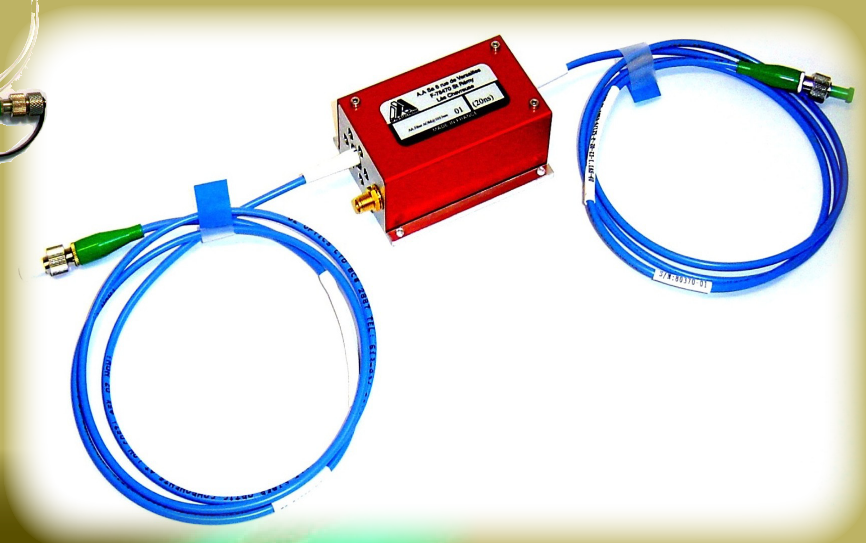
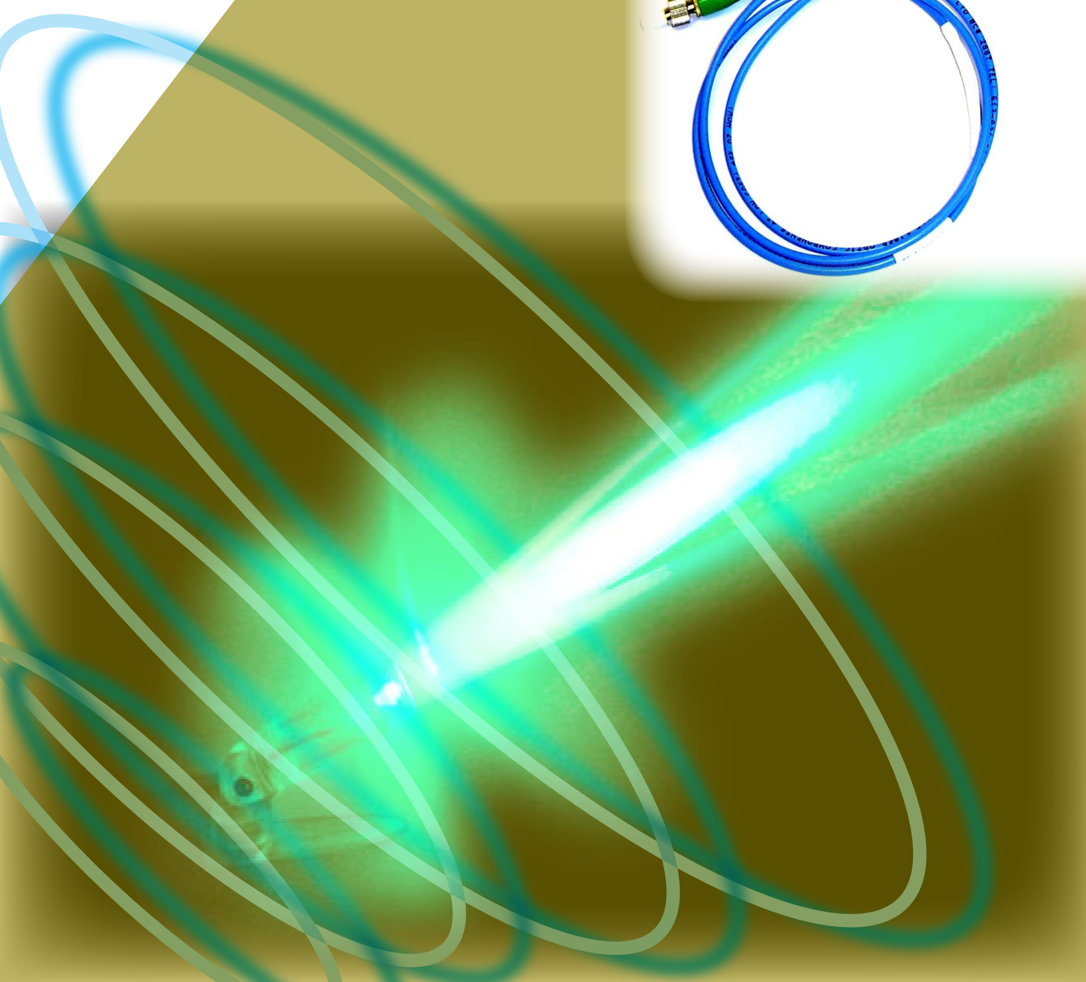
Acousto-optic products







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Introduction
Fibre Laser

A fiber laser or fibre laser is a laser in which the active gain medium is an optical fiber doped with rare-earth elements such as erbium, ytterbium, neodymium, dysprosium, praseodymium, and thulium. Fiber nonlinearities, such as Stimulated Raman Scattering or Four Wave Mixing can also provide gain and thus serve in effect as gain media. Unlike most other types of lasers, the laser cavity in fiber laser is constructed monolithically by fusion splicing the different types of fibers; most notably fiber Bragg gratings replace here conventional dielectric mirrors to provide optical feedback.

To pump fiber lasers, semiconductor laser diodes or other fiber lasers are used almost exclusively. Fiber lasers can have several kilometer-long active regions and provide very high optical gain. They can support kilowatt level of continous output power because the fiber's high surface area to volume ratio allows efficient cooling. The fiber waveguiding properties reduce or remove completely thermal distortion of the optical path thus resulting in typically diffraction-limited high-quality optical beam. Fiber lasers also feature compact layout compared to rod or gas lasers of comparable power, as the fiber can be bent to small diameters and coiled. Other advantages include high vibrational stability, extended lifetime and maintenance-free turnkey operation.

Many high-power fiber lasers are based on double-clad fiber. The gain medium forms the core of the fiber, which is surrounded by two layers of cladding. The lasing mode propagates in the core, while a multimode pump beam propagates in the inner cladding layer. The outer cladding keeps this pump light confined. This arrangement allows the core to be pumped with a much higher power beam than could otherwise be made to propagate in it, and allows the conversion of pump light with relatively low brightness into a much higher-brightness signal. As a result, fiber lasers and amplifiers are occasionally referred to as «brightness converters.»

Applications include: Material processing,telecommunications,spectroscopy, and medicine.

Fiber-hosted lasers

Solid state lasers also include glass or optical fiber hosted lasers, for example, with erbium or ytterbium ions as the active species. These allow extremely long gain regions and can support very high output powers because the fiber's high surface area to volume ratio allows efficient cooling. In addition, the fiber's waveguiding properties tend to reduce thermal distortion of the beam. Quite often, the fiber is designed as a double-clad glass fiber. This type of fiber consists of a fiber core, an inner cladding and an outer cladding. The index of the three concentric layers is chosen so that the fiber core acts as a single-mode fiber for the laser emission while the outer cladding acts as a highly multimode core for the pump laser. This lets the pump propagate a large amount of power into and through the active inner core region, while still having a high numerical aperture (NA) to have easy launching conditions. Fiber lasers have a fundamental limit in that the intensity of the light in the fiber cannot be so high that optical nonlinearities induced by the local electric field strength can become dominant and prevent laser operation and/or lead to the material destruction of the fiber.

Doped fibre amplifiers

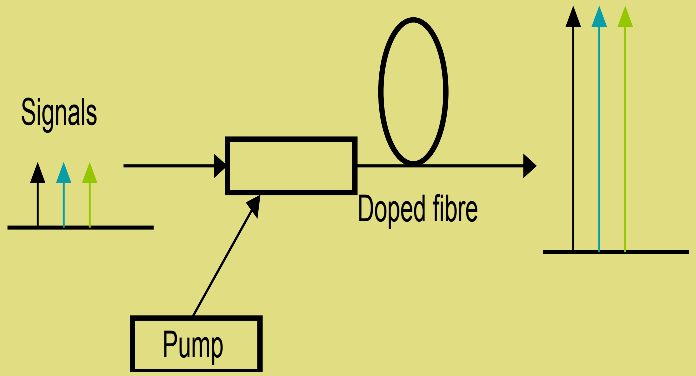
Doped fibre amplifiers (DFAs) are optical amplifiers which use a doped optical fibre as a gain medium to amplify an optical signal. They are related to fibre lasers. The signal to be amplified and a pump laser are multiplexed into the doped fibre, and the signal is amplified through interaction with the doping ions. The most common example is the Erbium Doped Fiber Amplifier (EDFA), where core of a silica fiber is doped with trivalent Erbium ions (Er^{+3}), can be efficiently pumped with a laser at 980 nm or at 1,480 nm, and exhibits gain the 1,550 nm region.

Amplification is achieved by stimulated emission of photons from dopant ions in the doped fibre. The pump laser excites ions into a higher energy from where they can decay via stimulated emission of a photon at the signal wavelength back to a lower energy level. The excited ions can also decay spontaneously (spontaneous emission) or even through nonradiative processes involving interactions with phonons of the glass matrix. These last two decay mechanisms compete with stimulated emission reducing the efficiency of light amplification.

The amplification window of an optical amplifier is the range of optical wavelengths for which the amplifier yields a usable gain. The amplification window is determined by the spectroscopic properties of the dopant ions, the glass structure of the optical fibre, and the wavelength and power of the pump laser.

Although the electronic transitions of an isolated ion are very well defined, broadening of the energy levels occurs when the ions are incorporated into the glass of the optical fibre and thus the amplification window is also broadened. This broadening is both homogeneous (all ions exhibit the same broadened spectrum) and inhomogeneous (different ions in different glass loations exhibit different spectra). Homogeneous broadening arises from the interactions with phonons of the glass, while inhomogenous broadening is caused by differences in the glass sites where different ions are hosted.

Different sites expose ions to different local electric fields, which shifts the energy levels via the Stark effect. In addition, the Stark effect also removes the degeneracy of energy states having the same total angular momentum (specified by the quantum number J). Thus, for example, the trivalent Erbium ion (Er^{+3}) has a ground state with $J = 15/2$, and in the presence of an electric field splits into $J + 1/2 = 8$ sublevels with slightly different energies. The first excited state has $J = 13/2$ and therefore a Stark manifold with 7 sublevels. Transitions from the $J = 13/2$ excited state to the $J= 15/2$ ground state are responsible for the gain at 1.5 μm wavelength. The gain spectrum of the EDFA has several peaks that are smeared by the above broadening mechanisms. The net result is a very broad spectrum (30 nm in silica, typically). The broad gain-bandwidth of fibre amplifiers make them particularly useful in wavelength-division multiplexed communications systems as a single amplifier can be utilized to amplify all signals being carried on a fiber and whose wavelengths fall within the gain window.



Acousto-optic Q-switches

Generation of optical pulses

Pulsed lasers have some advantages versus continuous lasers:

In some applications, such as optical communications, pulses convey information

Short pulses are used to achieve very large peak powers. All the emitted energy is compressed into very short pulses, so as to reach very large peak powers

Some applications rely on optical pulses to take snap-shots of very rapidly occurring process, such as fast chemical reactions, or electronic processes in semiconductors. Lasers can produce flashes of light that are many orders of magnitude shorter and brighter than ordinary flashlight

In some circumstances, it is the laser excitation mechanism itself that restricts the laser to pulsed mode operation, to reduce unwanted thermal load on the laser

A simple way to generate pulsed output is to put an optical switch (AO modulator for instance) at the output of a continuous wave laser (CW). By turning on and off, user can get pulses of light. For some applications, this is not efficient and this is preferable to use a switch (Q-Switch) inside the laser cavity. This has at least two advantages:

When the switch is closed, the laser cannot operate. This means the pump energy is not lost but stored in the active material in the form of excited atoms, or in the cavity in the form of light

When the switch is abruptly opened all the stored energy may be regained in a short pulse, generating peak powers that are many times higher than the average (CW) power.

Q-Switching

The Q or Quality factor of a laser cavity describes the ability of the cavity to store light energy in the form of standing waves. The Q factor is the ratio of energy contained in the cavity divided by the energy lost during each round trip in the cavity:

$$Q = 2\frac{\text{Energy stored in the cavity}}{\text{Energy lost in a cycle}}$$

This means that a cavity with high losses dissipates a lot of energy per cycle hence it has a low Q value. A high Q cavity means the energy loss per cycle is small in the given cavity.

By inserting a device in the cavity which is capable of controlling the loss of a cavity, we are effectively controlling the Q of the cavity. This device acts as an optical shutter or switch inside the cavity, which, when closed, absorbs or scatters the light, resulting in a lossy, low Q cavity. When the shutter is open, the cavity becomes low loss, high Q. This switch is called a Q-SWITCH.

Acousto-optic Q-Switches

A Q-switch is a special modulator which introduces high repetition rate losses inside a laser cavity (typ 1 to 100 KHz). They are designed for minimum insertion loss and to be able to withstand very high laser powers. In normal use an RF signal is applied to diffract a portion of the laser cavity flux out of the cavity. This increases the cavity losses and prevents from oscillation. When the RF signal is switched off, the cavity losses decrease rapidly and an intense laser pulse evolves.

It is essential in Q-switching to correlate the timing sequence of the optical pumping mechanism with the Q-switching. This means the following :

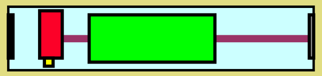
Assume that at the time when the laser pumping is turned on, the Q of the cavity is low. The high loss prevents laser action occurring so the energy from the pumping source is deposited in the upper laser level of the medium

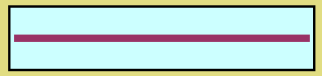
At the instant, when the population inversion is at its highest level, the switch is suddenly open to reduce the cavity loss

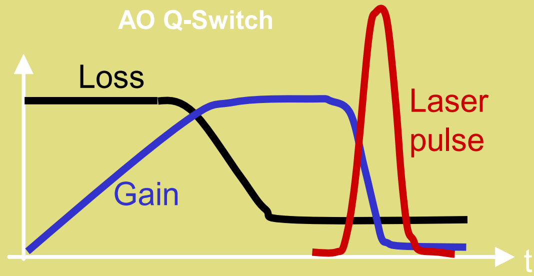
Because of the very large built up population difference, laser oscillations will quickly start and the stored energy is emitted in a single giant pulse

The lasing stops because the pulse quickly depopulates the upper lasing level to such an extent that the gain is reduced to below threshold.

This operation is periodically repeated in order to obtain the operating regime.



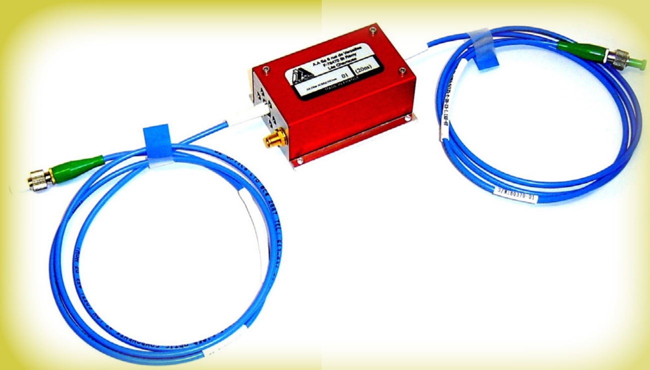




Fibre Modulators and Q-switches

1000 to 1100 nm

MT110-IR20-FIO 1000-1100
Fiber: SM, PM
Rise/fall time: 20 ns
Carrier frequency: 110
Insertion Losses: Nom 2.5 dB
Laser Power: 5 W



MT80-IR60-FIO 1000-1100
Fiber:: SM, PM
Rise/fall time: 60 ns
Carrier frequency: 80 MHz
Insertion Losses: Nom 1.5 dB
Laser Power: 5 Watts

3 Ports Fiber pigtailed Model Wavelength

MT80-IR60-3FIO 1000-1100
Fiber: SM, PM
Rise/fall time: 60 ns
Carrier frequency: 80 MHz
Insertion Losses: Nom 2.5 dB (orders 0+1)
Laser Power: 5 Watts
Pigtailed orders : 0 +1st orders