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ANALYSIS OF FEATURES WORKS OF OPTICAL FIBER AMPLIFIER

Abstract. *The work is devoted to a review of various options for fiber optical amplifiers, their principles of operation, advantages and disadvantages. The method of simultaneous Stokes and anti-Stokes stimulated Raman scattering of gain in fibers is also considered.*
Keywords: *optical amplifier, fiber, wavelength, gain, Fabry-Perot diode*

Optical amplifiers are devices that amplify an optical signal directly, without converting it into an electrical signal, which is amplified in the optical range.

Optical amplifiers are laser devices without an optical cavity or laser. Optical amplification is based on stimulated emission. The first design was a quantum generator of the optical range - a laser, in which feedback was carried out using a system of two flat mirrors parallel to each other. In the early stages, the researchers considered its enhancement.

Semiconductor optical amplifiers are based on the same technology based on Fabry-Perot laser diodes. To obtain only the amplification effect, resonance must be avoided. For this, an antireflection coating is used on the end faces of the crystal and a number of other means that suppress feedback. These devices are characterized by high noise levels, low gain, and high non-linearity and fast transients. Small dimensions allow them to be integrated with semiconductor lasers, modulators. Pumping is carried out by applying a voltage to the crystal.

Currently, amplifiers based on the Raman effect, based on doped optical fibers, are most widely used in optical communication systems.

The rare earth element erbium is added in small amounts to a piece of silicon core fiber. During the passage of an attenuated signal through it, a pump laser introduces a light beam with a slightly shorter wavelength.

For pumping, a laser diode emitting at a length of 1480 nm is used. And so the interaction with the quanta of the pumping light beam, the electrons in the erbium ions move to a higher quasi-stationary energy level. When a signal with a wavelength corresponding to the transparency window of the fiber passes through such a segment, induced radiation with an equal or very close wavelength occurs. Amplification is usually achieved in the 1530–1640 nm wavelength range [10–16].

When transmitting optical signals over fiber communication lines over long distances, due to scattering and absorption, weakening the information signal, it is necessary to use sequentially located amplifiers - repeaters. There are two types of repeaters - optoelectronic, based on the conversion of light - electronic signal - light, and fully optical, which have recently become widespread. Fiber amplifiers based on the forced emission phenomenon (FEA) in fibers doped with ions of rare earth metals, as well as Romanov amplifiers, which use the nonlinear optical effect of stimulated Raman scattering (SRC) in fibers, are used as all-optical repeaters. Such systems amplify optical signals in a relatively wide frequency range, including tens and hundreds of information channels, multiplexed in wavelengths. They are insensitive to data transfer rates up to 100 Gb / s and work with any data transfer formats [1-7].

Hybrid amplifiers

None of the existing types of optical amplifiers can satisfy all the modern needs of telecommunication systems, therefore, at present, new types of optical amplifiers are being actively developed.

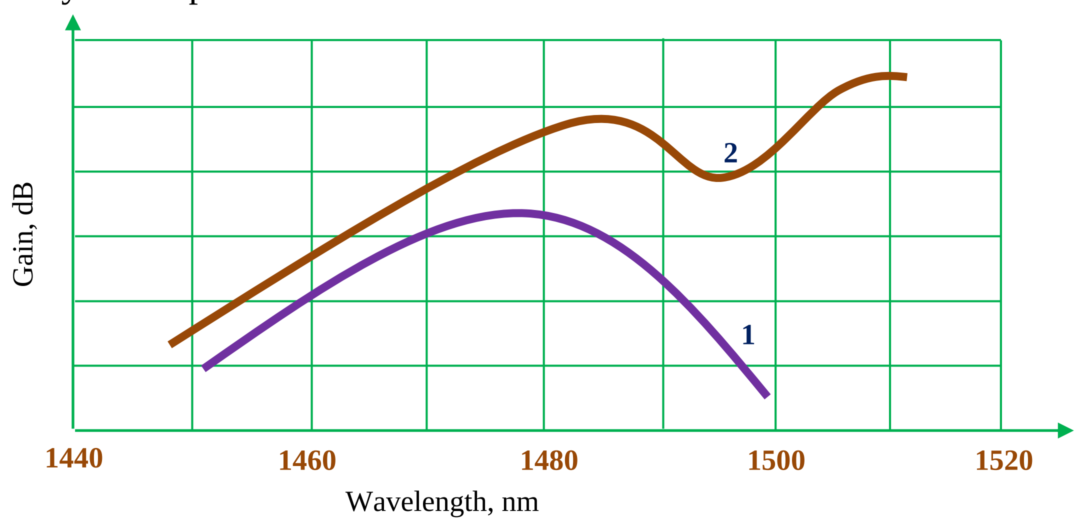

Fig. 1. Spectral curves of stimulated Raman amplification - amplifier pumped at one (1) and two (2) wavelengths

Due to the fact that the gain band of stimulated Raman scattering - amplifier can be shifted towards higher or lower frequencies with respect to the gain band of an erbium fiber amplifier [5, 6], when using sufficiently powerful pump lasers, the amplifiers can be matched in such a way that the resulting the gain bandwidth was much wider than that of each of the amplifiers separately. This can significantly smooth out the unevenness of the gain curves of individual amplifiers (Fig. 2).

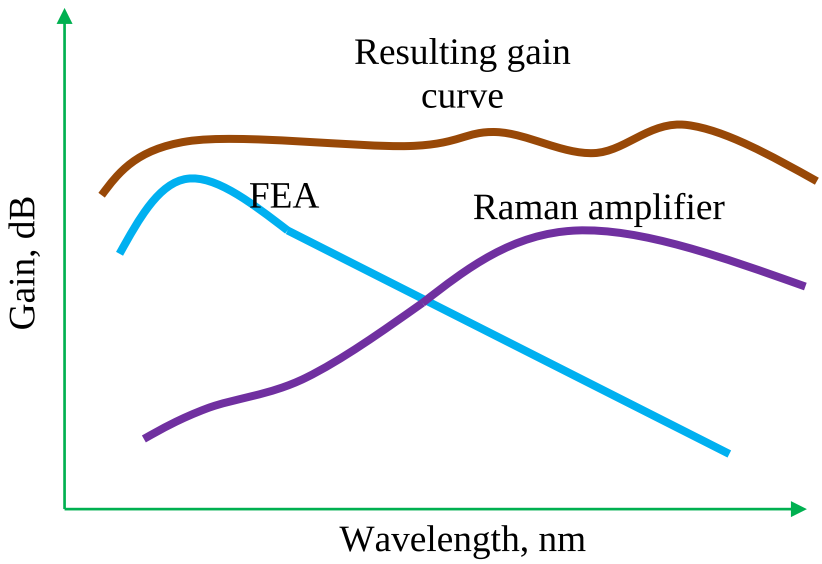

Fig. 2. Smoothing the overall gain curve when using stimulated Raman scattering - amplifier and erbium fiber amplifier

An experimental system developed in the laboratory of Nortel Harlow (Essex, England), using this hybrid scheme, provided the transmission of 32 spectral channels over a distance of 1000 km with a bandwidth of each channel of 40 Gb / s with a total transmission rate of 1.28 Tb / s [5].

Stokes anti-Stokes stimulated Raman amplifiers

For simultaneous amplification in the transparency windows of 1310 and 1550 nm of silica fiber, it is possible to use a combined Stokes and anti-Stokes stimulated Raman scattering - amplification in conditions of phase quasi-phase matching [5-6]. To ensure the condition of phase quasi-phase matching, the fiber must consist of alternating regions with nonlinear properties (active layers) and without nonlinear properties (passive layers). The thickness of the layers should be chosen so that in each active layer there is an efficient transfer of energy from the pump wave to the anti-Stokes component of the erbium fiber amplifier.

The main properties of phase quasi-phase matching were studied in detail in [8]. Calculations carried out using this technique have shown that the fiber length, at which the gain reaches 13 dB, is approximately 3 km.

Due to the wide amplification band of the silica fiber of stimulated Raman scattering, the amplification occurs not at one frequency, but in a certain frequency band (Fig. 3) [5-6]. Since the layered structure remains unchanged in a wide pumping wavelength range (1400 ... 1500 nm), pumping at several wavelengths can be used to increase the amplifier power, increase and smooth the gain bands [10-13].

Simultaneous Stokes and anti-Stokes stimulated Raman scattering - amplification has all the advantages and disadvantages of Stokes stimulated Raman scattering - amplification (while the resulting gain is slightly reduced). The main disadvantage of this method is the high complexity of the implementation of a layered structure consisting of a large number of layers.

Currently, only erbium-based all-optical amplifiers are actually used in fiber-optic communication lines, although their capabilities are clearly insufficient to meet the requirements applied to the next generation telecommunication systems [14-16].

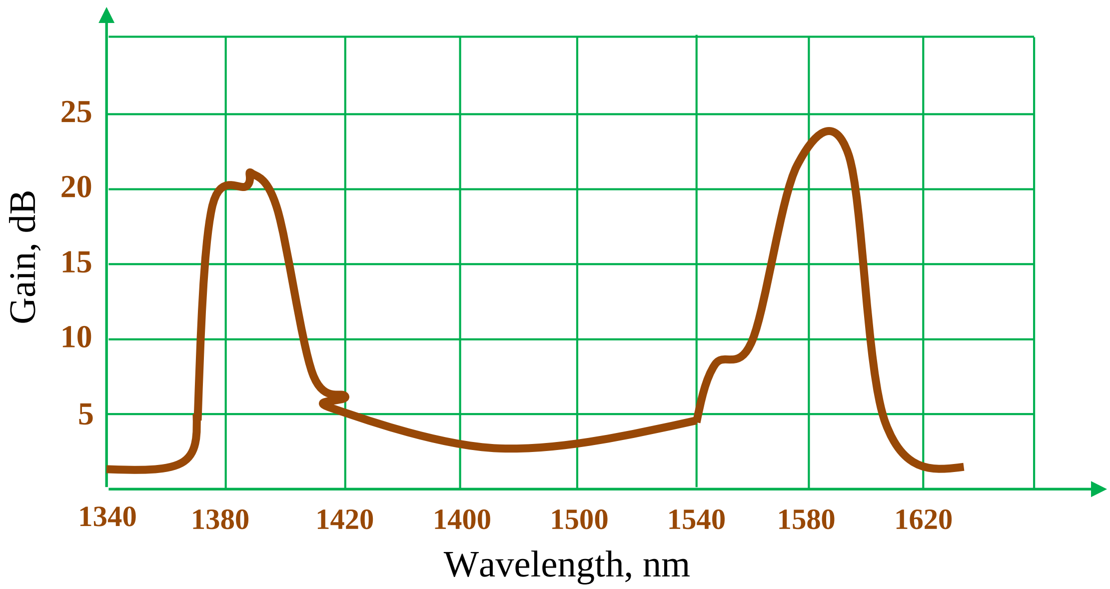

Fig. 3. Spectral curve of Stokes and anti-Stokes amplification in a quartz fiber

To increase the bandwidth (the number of spectral channels), it is necessary to use hybrid amplifiers that smooth the gain curve. Implementation of a hybrid amplifier with simultaneous Stokes and anti-Stokes amplification will increase the bandwidth. With increasing data transfer rates, the relatively low speed of erbium amplifiers will cause a number of problems, as a result of which stimulated Raman scattering - amplifiers will take a leading position in the market for fiber optical amplifiers.

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