GaAs based optical devices for Telecommunications

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Abstract

Up to now, for the telecom applications, the optoelectronic components are mainly used in the transmission systems. Due to the higher properties of the optical fiber at 1,3 and 1,55µm wavelengths, InP based adapted components were studied replacing first 0,85µm GaAs based laser diodes. Nevertheless for the short distance transmission links and due to the lower cost, GaAs based laser diodes are always industrially used.

Among the different research activities devoted to the telecommunication aspect, two of them are of strong interest for optical amplification and optical interconnection.

The recent boom on optical doped fiber amplification and the need of adapted pump laser has recently strongly improved research activities on 0,98µm laser diode. These GaAs based lasers are using "a strained quantum well vertical structure". The laser structure is shortly described. High performances are obtained with a CW optical power ≈ 150mW for only ≈ 200mA. Commercial products are already available but important research activity is still in progress.

Finally due to the higher and higher bit rates needed in the telecommunication industry, optical interconnection is becoming an important technology. It allows to simplify the development of the sophisticated equipments. Several channels (> 4), with high bit rates (622 Mb/s ; 2,5 Gb/s) are used in parallel which need the development of adapted laser arrays. GaAs based lasers are studied in several companies and the paper focuses on the new vertical cavity surface emitting laser.

Past evolution. Importance of GaAs based light emitters

Optical technology for telecommunication applications is still very new. It was only in 1966 that KAO and HOCKAM proposed the use of a silica fiber as a transmission carrier.

The driving force behind the progress of optical technology has been the evolution of basic components performances which determine the performances of transmission systems. It was soon recognised that the optical fiber possessed considerable potential in term of bandwidth which dictates data transmission rate, and the absorption coefficient on which maximum transmission distance is dependant. To obtain the benefit of these potential advantages, it was necessary to study and develop components suitably adapted, with particular reference to optoelectronic termination components.

For a long time these components were used as simple electro-optical transducers. At the transmission end, a coded electrical signal must be converted into an equivalent optical signal, which is then injected into the optical fiber. A LED (Light Emitting Diode) or a laser diode is used for this purpose, according to required performance. During the 1970 years a "window wavelength" around 0,85µm was used. Materials derived from Ga As were used for the emitters. The first laser diode, based on stacks of GaAs/Ga Al As, capable of continuous operation around 0,85µm at room temperature appeared in only 1970.

The use of a 1,3µm and then 1,55µm wavelength has led to a considerable reduction in attenuation of the signal transmitted via the fiber. Adapted components derived from InP were developed replacing GaAs based laser diodes.

Today the first window around 0,85µm is always industrialy used for some short distance transmission links at low or medium bit rate.

New applications for GaAs based optical devices in Telecommunications

Among the different fields of research activities on the GaAs based optoelectronic devices for telecommunication applications, two of them are of short term interest in relationship with optical fiber amplification and the optical interconnection.

1) 0,98µm pump laser diode for optical fiber amplifiers

Up to now in long distance transmission links, complex repeaters including electrical ↔ optical conversions are currently used. The replacement of these repeaters by transparent optical amplifiers has long been a dream. Recently in 1987 the Erbium doped fiber amplifier (EDFA) was experimentally demonstrated as a practical solution. It permits optical amplification around 1,55µm wavelength. Extremely rapid progresses were obtained and today EDFA begin to be used at an industrial level.

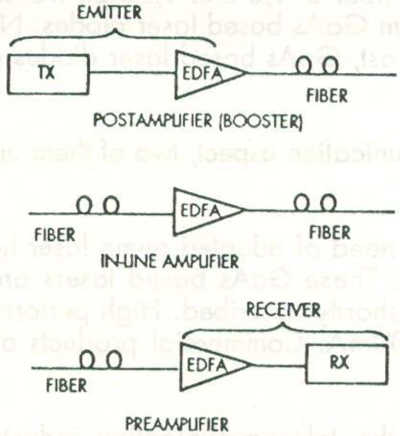

FIG. 1 - POSITION OF OPTICAL AMPLIFIER IN NETWORK

As shown in figure 1 depending in its position in the network, an optical amplifier is either a postamplifier (booster) increasing the output power of the transmitter, or an in-line amplifier bridging two network fibers (to replace a repeater), or an optical preamplifier situated in front of the receiver.

Figure 2 gives the basic configuration of an erbium doped fiber amplifier. The gain medium is a fiber doped with a very small amount of a rare earth ion, erbium, having a laser transition in the 1,55µm wavelength window of optical communications. To induce gain in the doped fiber, the laser transition is optically pumped by a laser diode, the optical pump power being combined inside the fiber core by a wavelength multiplexer.

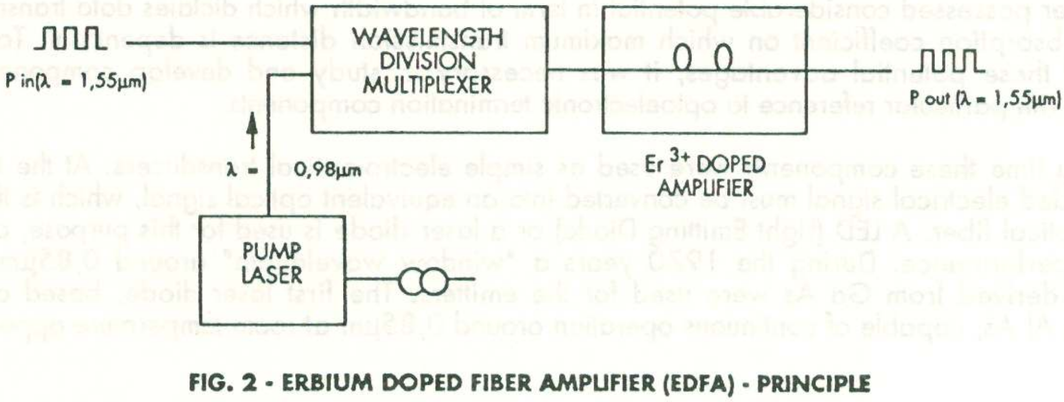

FIG. 2 - ERBIUM DOPED FIBER AMPLIFIER (EDFA) - PRINCIPLE

Among the available absorption bands of the erbium ion, two wavelengthes appear excellent : 1,48µm and 0,98µm. 1,48µm laser diode is InP based, 0,98µm laser diode is GaAs based.

The advantages of the 0,98µm laser pumping concern a lower amplifier noise and a lower electrical consumption.

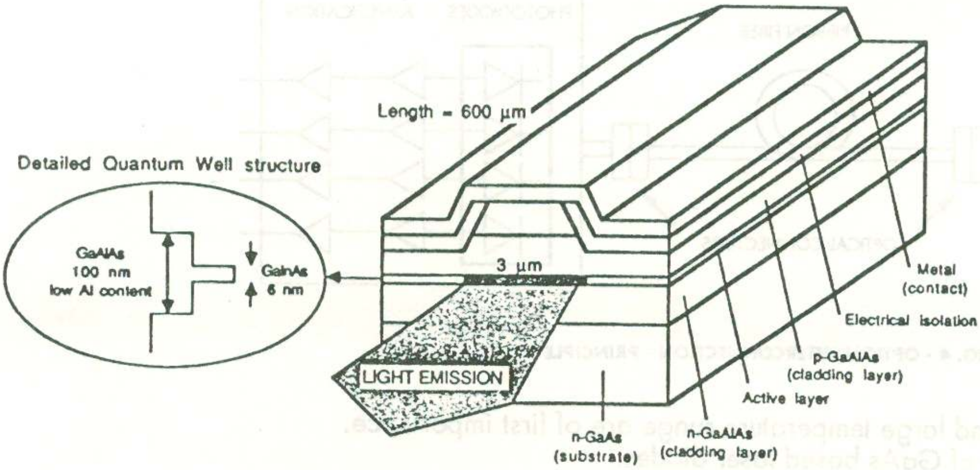

FIG.3 - 0,98 µm PUMP LASER DIODE

Basically the pump laser structure as shown in figure 3 is a classical laser diode. It is a diode consisting of multiple epitaxial layers grown on a GaAs substrate. The "active layer" is sandwiched between n and p type cladding layers of GaAs. A bias current applied to metalic contacts provides the action layer with a supply of electrons and holes which recombine, emitting light at a wavelength determined by the active layer's energy gap. A stripe structure is used to laterally confine both electrically and optical "energies".

To obtain high CW power performances at 0,98µm, the vertical structure is improved (figure 3) using a "strained quantum well" structure. A very thin ≈ 6nm "strained" GaInAs "active" layer is sandwiched in a low Al contents GaAlAs layers (≈ 100nm) which provide the optical confinement.

The stripe width realised using a "ridge structure" is around 3µm. The cavity length is around 600µm.

Due to the high emitted optical power (≈ 150mW), facet passivation is of first importance to avoid mirror degradation (Catastrophic Optical Damage (COD)).

Presently the high performances obtained are summarised in the next table :

. Single mode laser emission
. CW optical power ≈ 150 mW
. Beam divergence : < 14 degrees parallel to the junction
< 30 degrees perpendicular to the junction

2) Laser arrays for optical interconnection

Due to the higher and higher bit rates needed both for telecommunication and computer industries, optical interconnection becomes a key technology. It simplifies the hardware architecture and the realisation of sophisticated equipments such as high capacity crossconnects, high bit rate Add and Drop Multiplexors ...

It concerns shelf to shelf, board to board and back panels multichannel data connections. So distance of transmission is relatively short and low attenuation of the optical fiber is not a first requirement. In these conditions "short" wavelength transmission (around 0,8µm) is of interest.

The figure 4 gives a schematic presentation of an optical interconnect system. Multiple laser beams are multiplexed in parallel and fits into ribbon fiber. The transmitting section contains a laser diode array, the receiving section contains a photodiode array. Number of channels may vary from 4 to 10. A channel bit rate as high as 2,5Gb/s may be required for the telecommunication applications.

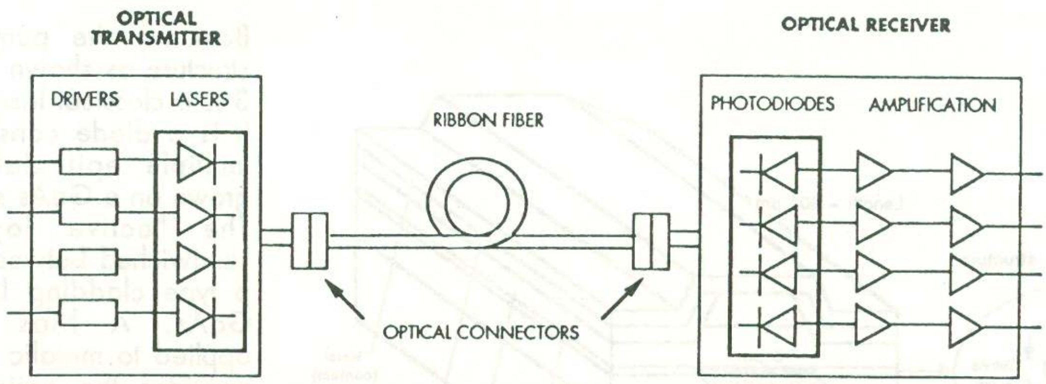

FIG. 4 - OPTICAL INTERCONNECTION - PRINCIPLE

Low electrical consumption and large temperature range are of first importance. These arguments are in favor of GaAs based laser diodes.

To perform laser array emitters two approaches are today studied which concern, two different categories of lasers : "edge" emitters and "surface" emitters.

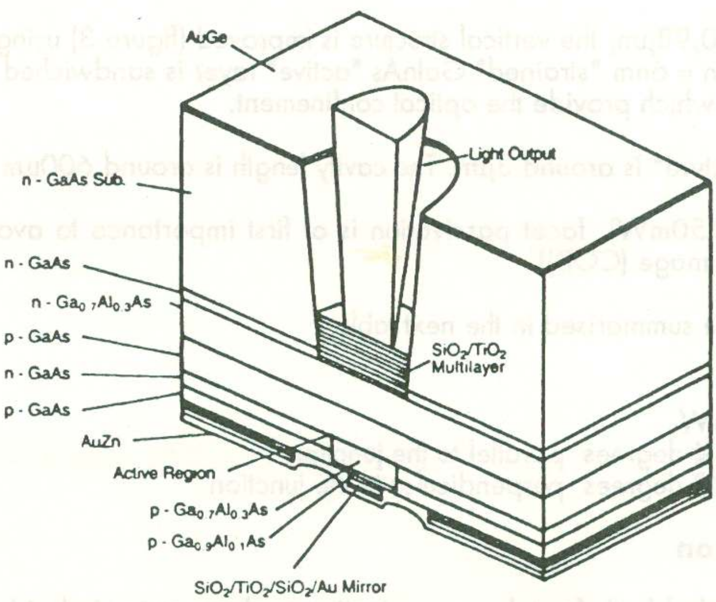

FIG. 5 - VERTICAL CAVITY SURFACE EMITTING LASER

The edge emitter is the classical approach. Mirror facets are realised using "cleavage planes" and light is emitted at the extremity of the laser stripe. The Vertical Cavity Surface Emitting Laser (VCSEL) corresponds to a new approach (figure 5). This component is extremely promising with very interesting characteristics as a low threshold current and a circular beam with a low divergence. Moreover, collective processing and testing will probably permit to strongly decrease the price. Important technological problem as the mirror realisation are to be solved. Nevertheless the first commercialised products already exist. Obviously a large research activity is always underway both for GaAs and InP based VCSEL's.

Conclusion

Even if for transmission systems, the research on optoelectronic devices is mainly focused on InP based components, some important applications as optical amplification and optical interconnection always justify research activity on GaAs components. Obviously even if not treated in this paper, an important research activity concerns GaAs based electronic devices associated to optoelectronic components.