AOARD REPORT

Int'l Conference on Optical Amplifiers and Thier Applications in Yokohama

July 4-6 1993

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At the International Conference on Optical Amplifiers held in Yokohama, Japan on 4-6 Jul 93, the following two topics were discussed which were of particular interest to readers. (1) The 1.5 micron erbium doped fiber amplifier has been established as a key component in optical communications. Now, new doping materials, such as praseodymium and thulium, which operate at 1.3 and 1.47 micrometers, respectively, are emerging as other candidates for optical communications and have been studied very actively in the past few years. (2) In the area of ultrahigh speed optical transmission systems, characteristics of optical solitons are being studied in-depth as seen by numerous contributing papers on this topic. The results of optical soliton experiments look very promising for the future use of deep-sea transoceanic transmission systems.

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Subject: Trip Report - Conference on Optical Amplifiers and Their Applications, held in Yokohama, Japan Between 4-6 July 93

ABSTRACT:

The International Conference on Optical Amplifiers was held in Yokohama, Japan, on 4-6 Jul 93. The current issues associated with properties of fiber-based and semiconductor optical amplifiers, realization of optical amplifiers in a variety of discrete and integrated forms, novel applications of optical amplifiers, subsystem designs for long distance communications, system demonstration and associated technologies of optical communications systems were discussed.

In this conference, the following two items were of particular interest. (1) The 1.5 micron erbium doped fiber amplifier has been established as a key component in optical communications. Now, new doping materials, such as praseodymium and thulium, which operate at 1.3 and 1.47 micrometers, respectively, are emerging as other candidates for optical communications and have been studied very actively in the past few years. (2) In the area of ultrahigh speed optical transmission systems, characteristics of optical solitons are being studied indepth as seen by numerous contributing papers on this topic. The results of optical soliton experiments look very promising for the future use of deep-sea transoceanic transmission systems.

Purpose: To participate in international forum concerning the current issues associated with properties of fiber-based and semiconductor optical amplifies, realization of optical amplifies in a variety of discrete and integrated forms, novel applications of optical amplifiers, subsystem designs for long distance communications, system demonstration and associated technologies of optical communications systems.

Place and Time: The conference was held at the Pacifico Yokohama Conference Center in Yokohama, Japan between 4-6 July 1993.

Observations/comments:

A total of 89 papers were presented, consisted of 55 oral (1 plenary, 9 invited, 45 contributed), 22 poster, and 12 post-deadline papers in the three day conference. At the final count, there were 212 people registered for the conference. The majority of them came from Japanese industrial research laboratories, such as Nippon Telephone and Telegraph (NTT), NEC, Mitsubishi, Fujitsu, Hitachi, and KDD. Foreign participants were from the US, Denmark, Great Britain, South Korea, Mainland China, Sweden, France, Germany, and Israel. The conference was sponsored by Optical Society of America, IEEE/Lasers and Electro-Optics Society, IEICE Communications Group, Japan, and IEEE/LEOS, Tokyo, Japan. The partial support came from US Air Force Office of Scientific Research; the Asian & Pacific Areas Assembly for Telecommunications Systems, Japan; the International Communications Foundation, Japan; and the Telecommunications Advancement Foundation, Japan.

The conference was divided into 13 oral sessions, which included the opening remarks and post-deadline papers, and 1 poster session. Topics discussed were mainly dealing with fiber amplifiers and their sources, semiconductor amplifiers and its pump lasers, amplifier integration, applications, theory of designs and its applications, and some other related technologies such as couplers, splitters, optical filters, optical isolators, packaging, and reliability.

In the area of doped material fiber amplifiers, erbium and praseodymium are used for optical signal amplification for optical network and communications systems. Erbium is used to amplify the optical signal at 1.5 um and praseodymium is used at 1.3 um over the long distance communications. These doped fiber amplifiers provide high gain and low noise performance and are suitable for high efficiency and polarization insensitive operations. On the other hand, semiconductor optical amplifiers (SOA) are used primary for the compensation of optical signal losses in photonics integrated circuits at such places as coupling interfaces, inside waveguides, and within passive and active component devices.

Plenary speaker Prof Rod Tucker, director of Photonics Research Laboratory at the University of Melbourne, Australia, described various applications of optical amplifiers. In addition to the main function of boosting up the optical signals for transmission systems, the optical amplifiers can be used for switching, gating, frequency shifting, and signal detection. He gave a good overview of the diverse range of applications in which optical amplifiers can play a role. The talk explained in detail how the building-block model of optical amplifiers can now be extended to multiple-function devices, and he highlighted the versatility of SOA's and doped material fiber amplifiers' in a range of photonics and lightwave circuits networks and systems.

The title of the second session was "Polarization Insensitive Semiconductor Optical Amplifiers". Of four papers presented in this session, three papers discussed the polarization insensitive characteristics of semiconductor optical amplifiers. These papers reported the polarization insensitive optical gain of more than 20 dB with less than 1 dB gain difference in TE and TM polarized waves. This resolves one of the major issues for SOA and makes SOA more competitive than optical material fiber amplifiers, due to SOA's compact features and broader wavelength operations. The fourth paper by a group of Hitachi researchers has reported the lossless and low crosstalk performance of 4x4 carrier injection type optical switch with travelling wave amplifier. This optical device showed the fiber to fiber gain of 5 dB with extremely low crosstalk and raised the hope in using this type of the device for large capacity photonic switching networks.

There was a session that dealt primary on system implications of dispersion and polarization effects of optical amplifier systems. Compensation techniques reported here consisted of nonlinear optical phase conjugator, the use of dispersion compensation fibers in coherent in-line amplifier systems, chirp compensation and modified principle states transmission mode. Of these techniques proposed here, I found the modified principle states transmission mode technique to be very intriguing since the proposed idea can suppress the influence of polarization mode dispersion in long span optical repeater systems. In 1.0 km transmission tests, it has demonstrated almost the penalty free operation resulting in one bit error rate characteristics.

In the session that focused on new doped optical fiber amplifiers, two new types of doped amplifiers were introduced. One type is the thulium (Tm) doped fluoride amplifier, which operates at 1.47 um and 1.9 um using 1.064 um and 1.58 um pump lasers, respectively. The second type is the Yttrium doped silica amplifier, which operates at 1.02 um using a 0.98 um pump laser.

In the area of new fiber gain wavelengths, Yoshiaki Miyazima and his co-workers from the NTT Telecommunication Fields Systems R&D Center reported the demonstration of a 1.465 um Tm-doped fluoride fiber amplifier using a Ti:Sapphire laser that is operated at 1.064 um. It was accomplished by using a 10 meter long Tm fiber at a Tm concentration level of 200 ppm. The maximum gain of 30 dB was achieved using the pump laser power level of 550 mw with the background loss of about 0.1 dB/m as a result of scattering. One application of the 1.465 um Tm-doped amplifier is to use the output as a source for the erbium doped fiber amplifier to obtain 1.5 um at high conversion efficiency of over 80%.

Another NTT group headed by Takashi Yamamoto presented in the first time the result of exciting 1.9 um in Tm doped fiber using a 1.58 um erbium doped pump laser. They measured the maximum output power of 51 m Watts when pumped at 104 m Watts. The reason for investigating the production of 1.9 um is that it has a lower power loss through the fiber optics transmission lines than 1.58 um.

The French group headed by J.Y. Allain reported the results of producing the output power level of 1 watt from a 1.019 um yttrium doped fiber laser that was pumped by a 975 um tunable Ti:Sapphire laser with 50% conversion efficiency. The reason for investigating the 1.019 um laser is that it can be used as a very efficient pump source for a 1.3 um praseodymium optical amplifier.

In the area of erbium doped fiber amplifiers (EDFA), Kobayahsi et al of Hitachi Cable, Ltd presented in the first time the experimental results of a reflective erbium doped fiber amplifier pumped by a 1.48 um diode laser. The unique feature of this type of the amplifier is that both the pump and the excited signal are twice passed through the gain medium by using optical circulators and reflectors. Experimental data showed that the reflective EDFA has achieved twice the gain efficiency of the conventional forward pumped EDFA, however, with an increased amount of noise. Their experimental measured values were in good agreement with calculated values based on modelled two level rate equations.

Use of the erbium doped fiber amplifiers for long distance transmission, such as transoceanic fiber optics communications, has made remarkable progress in recent years. To achieve ultra high speed optical transmissions, a group at NEC presented the results of the newly developed optical amplifier repeaters experiment, which utilized the series of short length normal optical fiber and the high output power optical amplifier. The advantage of this system was that the high output power optical amplifier suppresses the noise generated in the fiber optics cable by nonlinear self-phase modulations at optical amplifier repeaters. The paper presented that the noise level was indeed suppressed and a 13 dBm signal increase was observed through a 1.5 um transmission line. Thus, the paper demonstrated that high output power optical amplifiers with optical repeaters have potential for low noise long distance communications.

In wave division multiplexed (WDM) systems involving several amplifiers, gain variations for different wavelengths resulted in different signal amplifications for output signals. Based a recent finding of the channel equalization amplifier using erbium doped twin core fibers, Zervas et al reported that an inhomogeneously broadened erbium doped amplifier can provide the greater amount of channel equalization. As compared to a perfect channel equalizing amplifier of 1 dB/DB amplitude difference, the group achieved 0.35 dB/DB for a two channel system. The finding will help to minimize the build up of channel amplitude errors in the future design of WDM systems.

In long haul systems, Kataoka et al of NTT laboratories attained the maximum bit transmission rate of 20 Gbits/sec over a distance of 400 km using high gain broad bandwidth erbium doped fiber amplifiers that employed 0.98 um laser diode pumped optical pre-amplifiers. Also another group headed by Takamasa Imai of NTT laboratories reported the experimental confirmation of transmitting 10 Gbits/sec over 3000 km with 100 km repeater spacing at the penalty value of 2dB by also using the erbium doped amplifiers. With these high bit rates over the long distance, one of the most promising applications will be in the area of underwater cable systems. It was mentioned in talk that it might be time to consider implementing the optical erbium doped amplifier technology in transoceanic communication systems.

Also presented in the long haul systems session were other repeater designs that meet the basic requirements for suitable deployment in undersea, transoceanic transmission systems.

In the area of 1.3 um band optical amplifiers, active research was carried out in praseodymium doped fluoride fiber amplifiers in the past three years due to the potential for high signal gain, wide amplified bandwidth, and high saturation output power. However, the low quantum efficiency for band stimulated transition of 1.3 um when pumped with a 1.017 um laser diode requires the system to have very efficient coulping going from 1.107 um to 1.3 um and also provide high pumping power from a 1.07 um laser diode system. NTT laboratories have invested a lot of efforts in producing a high gain praseodymium doped fluoride amplifier system. Makoto Yamada of NTT obtained a signal gain of 23 dB based on a highly efficient configuration that employed the optical circulator. Another NTT group headed by T. Sugawa reported the use of the nonlinear optical loop mirror in a 1.3 um praseodymium doped fiber amplifier system in order to generate a 1.6 u second pulse. This type of system can be applied in soliton communications where the ultra short pulse is transmitted through the transmission line without much dispersion over the long distance.

For the future of long distance and high throughput communications, NTT laboratories and KDD laboratories (both of them are Japanese communications companies) have explored the possibility of using optical soliton pulses. KDD reported the maximum transmission rate of 5 Gbits/sec in a fundamental soliton mode generated by sinusoidally driven InGaAsP electroabsorption modulator over a distance of 13,100 km with bit error rate of 1x10(-9). NTT reported the higher transmission rates of 20 and 40 Gbits/sec, however, at shorter distances of 1850 km and 750 km, respectively, with the use of erbium doped fiber amplifiers. Bit error rates for these two transmission rates were both reported at values less than 1x10(-10). Also reported by NTT was transmission of the soliton pulses at 10 Gbits/sec over 180 million km without much degradation. The input soliton had pulse and spectral widths of 0.08 nm and 30 ps, respectively. After travelling 180 million km, the transmitted soliton had pulse and spectral widths of 0.15 nm and 24 ps, respectively.

Based on these reports, it seems that it is possible to achieve almost error free transmission over unlimited distance using soliton pulses. In the future, more research is needed to increase the transmission rate to higher values in order to accomodate the high throughput communication.

Conclusion: The 1.5 um erbium doped fiber amplifier has been established as a key component in optical communications. Now, new doping materials such as presedomium which operates at 1.3 um and thulium whcich operates 1.47 um are emerging as other candidaes for optical communications and are being studied very actively in the past few years.

In the area of ultrahigh speed optical transmission systems, characteristics of optical solitons are being studied in depth as seen by numerous contributing papers on this topic in this conference. The results of optical soliton experiments look very promising for the future use of deepsea transoceanic transmission systems.