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Review of the Amplification techniques of a Fiber Laser

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Abstract

Fiber Lasers employ an optical fiber cable typically made of silica glass as its active gain medium. The optical fiber is doped with rare-earth elements such as erbium, ytterbium, neodymium, dysprosium, praseodymium, thulium and holmium. The paper authored by Charles Koester and Elias Snitzer utilizes a 1m long neodymium doped glass fiber on a pulsed basis to obtain gains as large as 5 x 10^4.This paper was the first experimentally demonstrated Fiber laser and is important to the field of optics because of the myriad of applications fiber lasers would go on to have.

Introduction

In the present-day rare-earth element, (elements such as erbium, ytterbium, neodymium and dysprosium) doped glass fiber provides an optical gain medium capable of producing high-power lasers with high brightness [1]. The geometry of the glass fiber provides a high surface-to-volume ratio that allows for excellent heat dissipation. This review analyses the first demonstration of a fiber laser, and the methodology of testing and the evolution of the applications of the laser.

In 1964 Koester and Snitzer attempted to obtain both stable high gain and high bandwidth by making the amplifier nonreciprocal [2].

Koester & Snitzer calculated intensity using the following formula [2]:

$$I_p = I_0 e^{(\beta - \alpha)x} \text{ (pumped).}$$

With β representing the gain per cm caused by population inversion due to pumping and α is the loss per centimeter caused by absorption and scattering. The formula for intensity used by Snitzer differs from what we studied in [3] (pg. 259), because the glass fiber medium is not allowed to reach saturation through control of the input signal. The gain of the laser is measured using [2]:

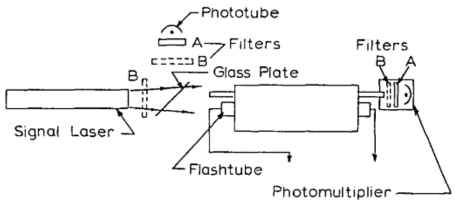
$$G = I_p / I_0 = e^{\beta l_p - \alpha l_t}.$$

Fiber lasers have many useful applications because they are produced by an inherently flexible medium, they can be targeted at the focusing location with greater ease. Secondly due to the fiber's high surface area to volume ratio they can support kilowatt levels of continuous power output, with efficient cooling [4].High power ytterbium fiber CW lasers operating around 1μm are absorbed well by metals and allows. Thus, they are ideal for high strength steel welding, cutting, and drilling. Tm^{3+} and Ho^{3+} fiber lasers are suited for plastic welding and cutting.

Methodology

Koester and Snitzer created a 1m fiber by cladding a neodymium doped glass core with clear glass of a lower refractive index. The assembly was wound into the form of a helix to allow them to conveniently pump it with a flash tube [2].

The source signal for amplification was provided with a neodymium glass laser rod as depicted in the extracted figure, a phototube was used to measure the laser output [2].



A large cladding to core ratio was needed to ensure total internal reflection and prevent signal loss, (typical diameters: 10µm for core and 0.75mm-1.5mm for the cladding). Another precaution the took was to destroy the light guide effect in the cladding by eliminating stray signals from the flashtube light. This was done by roughening the surface of the cladding. This allowed for a more accurate signal measurement.

Results and Discussion

The work of Snitzer and Koester proved that an optical fiber laser was not simply a theoretical model but could be physically achieved. However, their final result of a net gain of 5.3×10^4 was still lower than ruby lasers of the time. This was mainly in part due to the loss factor of the glass core they employed, Snitzer & Koester employed one of the first laser glasses they developed, which had a high loss coefficient $\alpha=0.022cm^{-1}$, core glasses they later produced had loss coefficients of $\alpha=0.001cm^{-1}$. Had Snitzer & Koester performed their experiment using the glass with the lower loss coefficient their gain would have been several times larger. This would have been a stronger argument for further research into fiber lasers, instead the field stagnated for about a decade before the modern resurgence in fiber laser applications.

Furthermore, the oscilloscope plots provided in the paper for the verification of the experimental results could have included an overlay of the output trace produced by the photomultiplier over the input signal of the neodymium glass fiber rod. This would have made the amplification factor more easily visually discernible.

Conclusion

The paper proved the feasibility of a fiber laser and displayed substantial gain in a 1m cavity. Furthermore, it displayed that the gain was a function of input pump power and gain measurement time. This paper was a seminal work in the field of photonics and would go onto inspire fiber laser research decades into the future, overall, it is a clear piece of scientific writing with verifiable and repeatable results.

References

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