CHAPTER 2

PULSED LASER EMPLOYING SATURABLE ABSORBERS IN MULTIPLE SPECTRA

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2.1 INTRODUCTION

In classical physics, light is defined as an Electromagnetic (EM) wave according to Maxwell's equation. The frequency of EM wave, ν, which is inversely proportional to the wavelength, λ, and having a constant group velocity in vacuum makes up the light spectrum. In conformity with quantum mechanics, the duality properties of light explain its wave and particle nature. A particle of light is commonly known as "photon".

Following the stages of development and object to be treated, optics can be classified into three categories, geometrical optics, physical optics, and quantum optics. Quantum optics, which appraise the interaction of light and matter by photon absorption and emission is fundamental in laser technologies.

A laser, abbreviated from light amplification by stimulated emission radiation, is an optical device or process that produces collimated, monochromatic and coherent light beams as the essential feedback of stimulated emission amplification. The fundamental factors for laser generation are a resonator, a gain medium, and a pumping source.

Fibre lasers utilise a rare-earth material doped optical fibre as an active gain medium, often with high optical gain and great stability, to produce high optical output power. In general, a pulsed fibre laser triggers enormous instantaneous power with ultrashort duration as compared to a Continuous-Wave (CW) fibre laser with moderately consistent optical output.

The generation of pulsed fibre laser makes it appealing, owing to its short data processing period and prominent optical intensities that result in a nonlinear optical effect in the laser gain medium. Generally, pulsed fibre lasers are classified into two, which are the Q-switched fibre lasers, which produce nanosecond pulses and the mode-locked fibre lasers, which produce ultrashort pulses.

2.2 CLASSIFICATION OF FIBRE LASERS

A fibre laser is a solid-state laser that adopts a tensile and glassy optical fibre doped with Rare-Earth Elements (REEs), specifically ytterbium (Yb^{3+}), erbium (Er^{3+}), holmium (Ho^{3+}), and thulium (Tm^{3+}) as active gain mediums for light emission through optical amplification. Optical fibre is popularly implemented for certain advantageous reasons:

(1) The light beam can be generated and distributed efficiently by an inherently extensible medium to the targets. This is propitious for laser cutting and welding technology, which amputate or concatenate metal or polymer components by concentrating high-intensity light beam to a desired spot.

(2) Kilometre-long active region of fibre laser contributes exorbitant optical gain that undeviating leads to a high output power against other types of lasers.

(3) The thermal distortion of the optical path is near-ideal and offers diffraction-limited and stringent criteria optical beams due to the waveguide nature of fibre.

(4) Fibre lasers possess excellent potential to withstand temperature and vibration, which makes them reliable and sustainable with longer lifespan.

Besides this, a human hair-like fibre is compact and lightweight, cost-efficient, and immune to Electromagnetic and Radio-Frequency Interferences (EMI & RFI). Furthermore, it has low transmission losses and magnificent tensile strength with ruggedness and flexibility of which establish the precedence of fibre lasers.

In general, fibre lasers can be classified into two, which are, CW and pulsed fibre lasers. A CW fibre laser is symbolised by its steady and constant output beam along with time as long as there is consistent and uninterrupted pumping. The gain energy of a CW fibre laser is fibre geometry dependent. As a result, self-terminating laser transitions are often incompatible with CW operations and are powerless to constitute ordinarily in the furtherance of population excitation especially at lower energy levels. The time-variant amplitude is holistically measured in nanoscales. The advantages of CW lasers—consequentially steady output on average over a long lifetime and significantly high-recurrence power variations—have a small impact in certain applications, nevertheless a significant proportion of lasers still refers to it.

Averse to CW fibre lasers, pulsed fibre lasers generate intermittent output and will commonly attain a giant pulse construed by its peak. The pulsed fibre laser exhibits significantly higher than average power in comparison, assuming the same input is supplied to both CW and pulsed fibre lasers. Hence, pulsed fibre lasers are commonly applied in the spheres of study demanding an eye-safe but high-intensity light beam in a short pulse period. Inherently, pulsed fibre lasers can be further subdivided into two types, which are Q-switched and mode-locked fibre lasers. A passive pulsed fibre laser has excellent stability actualised with the utilisation of easily fabricated and cheap saturable absorbers throughout its fibre structures; contrary to the active approach, which requires an external modulator, for instance, Acoustic Optical Modulator (AOM) and Electro-Optic Modulators (EOM).