What Is Random in Random Lasers?

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Despite the acronym, Lasers are actually optical oscillators where light is amplified by stimulated emission of radiation. These optical systems are formed by an optical amplification medium and a feedback mechanism. Like their electrical counterparts, the allowed oscillation frequencies (modes) are selected by the interference between multiple passages over the feedback path. Many different feedback architectures can be found in the literature, most of them unidimensional such as Fabry-Perot cavities, ring cavities or sigma cavities, either in free space optics or in guided wave configurations. Less frequent are examples of 2D or 3D feedback architectures, for which the mathematics involving oscillating modes is more complicated.

When random lasers were initially proposed as non-resonant feedback lasers back in the 60's, the feedback provided by light scattering was considered as a continuum and the sharp linewidth was attributed not to the open cavity but to the spectral properties of the gain medium. Even five decades later, with the development of Random Fibre Lasers, the concept of laser modes was still lacking and sharp laser lines were referred to as modes essentially because of their narrow linewidth. However, open cavity does not mean "cavity less" or "no-cavity" because the feedback mechanism necessarily defines closed paths and interference plays a fundamental role in the definition of laser modes. "Modeless" lasers are just Amplified Spontaneous Emission sources, not oscillators. The spatial properties of the laser modes will define the corresponding properties of the laser emission, in any 1D, 2D or 3D configurations.

Here an overview of random lasers within the framework of optical oscillators and lasing modes will be presented. Light scattering, in particular Rayleigh scattering, plays a fundamental role in the feedback mechanism in Random Lasers, being responsible for the randomness of these lasers. According to the overlap of gain and scattering media, Random Lasers can be classified as distributed gain or lumped gain lasers, a clear example of this distinction being the Raman Fibre Laser [1] in the former case and the SOA-based Fibre Laser [2] in the latter. On the other hand, depending on the statistical properties of the feedback mechanism, Random Lasers can be considered as stochastic or pseudo-random, depending on whether the feedback mechanism varies stochastically or it is a unique realization of a random variable.

The spectral and statistical properties of Rayleigh scattered light will be discussed as well as their role in the laser spectral properties and mode dynamics. Random Fibre Lasers and Rayleigh Backscattering will be used as a platform to describe and understand the more general category, including 2D and 3D cavity random lasers. It will be shown that while pseudo-random lasers provide extremely interesting properties on the field of sensing, stochastic random lasers find applications where the randomness and stochasticity are essential, such as in the generation of real random bit sequencies.

References

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