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G. Dattoli, E. Di Palma, S. Pagnutti, E. Sabia

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Free Electron Coherent Sources: from Microwave to X-rays

G. Dattoli[1], E. Di Palma[1], S. Pagnutti[2] , E. Sabia[1]

[1]*ENEA -Frascati Research Centre, Fusion and Technology for Nuclear Safety and Security Department, Via Enrico Fermi 45, 00044Frascati, Rome, Italy*

[2]*ENEA - Bologna Research Centre, Energy Technologies Department, Via Martiri Monte Sole 4, 40121 Bologna, Italy*

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ABSTRACT

The term Free Electron Laser (FEL) will be used, in this paper, to indicate a wide collection of devices aimed at providing coherent electromagnetic radiation from a beam of "free" electrons, unbound at the atomic or molecular states. This article reviews the similarities that link different sources of coherent radiation across the electromagnetic spectrum from microwaves to X-rays, and compares the analogies with conventional laser sources. We explore developing a point of view that allows a unified analytical treatment of these devices, by the introduction of appropriate global variables (e.g. gain, saturation intensity, inhomogeneous broadening parameters, longitudinal mode coupling strength), yielding a very effective way for the determination of the relevant design parameters. The paper looks also at more speculative aspects of FEL physics, which may address the relevance of quantum effects in the lasing process.

1. Introduction

The term Free Electron Lasers (FEL) is a fairly broad family of device including different sources that provide coherent radiation through a beam of free electrons, where "free" should be understood as not constrained in an atomic or molecular system.

Undulator based FELs (U-FEL) have become powerful tools for a variety of applications in physics. Since the first successful experiment in 1976 [1], the next forty years have yielded successful operation in different configurations like oscillators and single passage devices [2]. The associated advances in the technology of high brightness Linacs have allowed the production of X-ray beams with un-precedent characteristics in terms of coherence, flux and brightness.

The physical mechanisms underlying the U-FEL operation are generally well understood and will be reviewed i herein. Subsequently, the underlying mechanism of U-FEL will be used as pivot to establish a common thread with other Free Electron coherent sources.