Wide Band Compact FELs for Applications in the THz Region

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Abstract—**The rapid advance of terahertz technologies in terms of radiation generators, systems, and scientific or industrial applications has put a particular focus on compact sources with challenging performances in terms of generated power (peak and/or average), radiation time structure, and frequency band tenability. The aim of the present communication is to demonstrate the feasibility of a Free Electron Laser (FEL) achieving performance comparable to a conventional photoconductive THz source, which is commonly used for time-domain spectroscopy (TDS), in terms of bandwidth and pulse duration. We will also demonstrate that a THz FEL could be very powerful and flexible in terms of tailoring its spectral features.**

I. INTRODUCTION

TIME domain-based terahertz (THz) sources have gained more and more attention during the past 15 or 20 years [1], and these systems are now commercially available, reliable, and easy to use. A complementary and alternative approach, based on free electron devices, is discussed in the present communication, with the final aim to project a device for high power broadband THz applications.

The proposed source exploits all the coherence mechanisms that are known in FEL devices. The first is the bunched electron beam generated by RF accelerators. Coherence is, in this case, obtained when the electron bunch length is comparable to the wavelength of the radiation to be generated by the FEL [2]. A second degree of coherence is given considering the relationship among all the electron bunches. In fact, an RF accelerator generates a train of pulses, and if the correlation among all the consecutive pulses is good, the radiation will be emitted at discrete frequencies that are harmonics of the RF [2]. A third degree of coherence can be added if we treat the bunch as a collection of particles distributed in the longitudinal phase space; when the electrons in a bunch are distributed in the longitudinal phase space following an ideal curve [3], the radiation emission, due to each particle is added in phase, maximizing the power extraction during the interaction process.

II. THE STUDY PROJECT

A study project has been realised for a FEL operating from 0.5-1.5 THz. The device is an evolution of the ENEA CATS experiment [4] where the role of the Phase Matching device is now taken by a double frequency RF cavity (DFC). The use of a DFC requires the second frequency to be a harmonic of the fundamental one, in order to be resonant. There are some design parameters that can be set, such as the harmonic number and the relative amplitude ratio, that contributes to the bunch length, but the most relevant is the relative phase between the fundamental and the harmonic frequencies. These parameters establish the slope of the total field in the cavity right where the electron bunch passes.

In order to design an FEL operating at THz frequencies, simulation software that is capable of evaluating several of the characteristics of FEL sources has been developed [5]. This code makes use of the electric field generated inside the DFC, which is used as a phase-matching device. The electrons accelerated by a Linac are injected into the DFC that is fed with the fundamental (3 GHz) and fifth harmonic. The simulation result is reported in Fig.1 and indicates that after the proper optimization, a power spectrum, that ranges from 0.5 to 1.5 THz, is obtained. The integrated power over the macropulse duration and over the total spectral bandwidth, of about 90 kW. It is very important to stress that with this device, due to the RF properties of the accelerator, it is possible to isolate the single harmonic still having an average power for the single frequency of the order of hundreds of watts. This is not possible with conventional THz sources. Moreover, another interesting result is that the single frequency, being a harmonic of the RF, has a temporal structure equal to that of the RF macropulse. In addition, we have to refer to the RF macropulse for its temporal coherence, which for conventional magnetrons and klystrons is usually quite good. On the other hand, if we look at the whole bandwidth, the temporal structure is the well-known train of microbunches separated by the RF period.

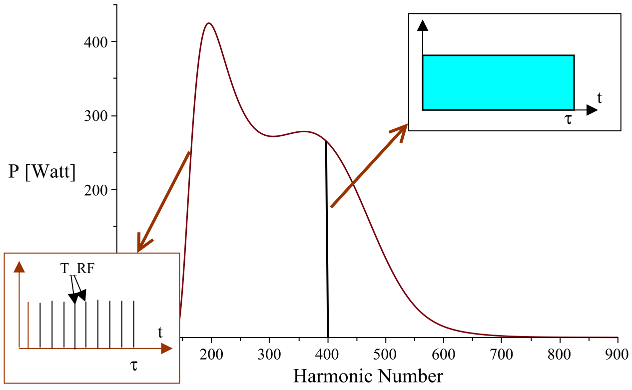

Fig. 1. Simulation of the optimized radiation power spectrum emitted as a comb of frequencies related to the harmonics of the fundamental RF (ν_{RF} = 3 GHz).

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