The CERN Accelerator School

Contribution ID: **46** Type: **not specified**

FEL II

Monday 18 November 2024 14:30 (1 hour)

The subject of this advanced course is a simplified treatment of the light amplification process in a free electron laser (FEL).
The first lecture deals with the so-called low gain FEL, where a "short"undulator is surrounded by an optical resonator. Starting with the calculation of the energy exchange between the electron beam and the radiation field, the ponderomotive phase is defined which remains constant when operating on resonance. The pendulum equations, linking this phase with the relative energy deviation from the resonance energy are derived and interpreted under the assumption that the radiation field will not change significantly during one pass through the undulator. Electron injection above resonance energy leads to an amplification of the radiation field. For low intensities, this is quantitatively described by the Madey theorem, which links the FEL gain curve with the spectrum of the spontaneous emission. For strong radiation, the gain curve will deviate significantly from the predictions of the Madey theorem and the gain will be reduced. Saturation and therewith stationary operation is achieved when the resonator losses are compensated by the FEL amplification.
The second lecture deals with an introduction to the dynamics of a high-gain FEL. Now dropping the assumption of a constant radiation field and assuming a slowly varying field amplitude and phase, these variations are derived from a simplified one-dimensional treatment. The additional field equation supplements the pendulum equations extending them to a system of coupled differential equations. Further insight is gained by the definition of normalized parameters simplifying this system of coupled equations to a single cubic differential equation. The cubic equation is investigated in detail by solving it for two different cases: amplification starting from an existing radiation field and amplification starting from an initial density modulation. Both situations will finally lead to an exponential growth of the light intensity for a sufficiently long undulator and beam injection on resonance. Important parameters like the gain length and the Pierce parameter are introduced and explained in detail. Finally, the SASE process is presented and the properties of the generated radiation is discussed. State of-the-art methods for decreasing the spectral width of the generated radiation and increasing its longitudinal coherence are sketched briefly.

Presenter: HILLERT, Wolfgang