Advanced High Power Gyrotrons for EC H&CD Applications in Fusion Plasmas

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The R&D activities at Forschungszentrum Karlsruhe (FZK) on advanced high-power mm-wave gyrotrons for future use in electron cyclotron heating and current drive (EC H&CD) in fusion plasmas consist of: (1) the development of a coaxial cavity gyrotron capable of delivering 2 MW continuous wave (CW) at 170 GHz and (2) investigations on tunable multi-frequency gyrotrons. In the case of the coaxial cavity gyrotron the feasibility of manufacturing multi-megawatt gyrotrons in CW operation has been demonstrated in proof of principle experiments at pulses around 1 ms. Problems specific to the coaxial arrangement have been investigated and information relevant for an industrial realization has been obtained. Based on these results the development of a coaxial cavity gyrotron with an RF output power of 2 MW, CW at 170 GHz as could be used for ITER started recently in cooperation between EURATOM associations (CRPP Lausanne, FZK Karlsruhe and HUT Helsinki) together with Thales Electron Devices (Velizy, France). To verify experimentally the design of the main components (electron gun, cavity and RF output system) of the industrial prototype, the previously used 165 GHz coaxial gyrotron at FZK has been redesigned for operation in the $TE_{34.19}$ mode at 170 GHz. The maximum magnetic field of the SC magnet at FZK of only 6.667 T requires a reduction of the operating voltage from 90 kV (as foreseen for the industrial prototype) to 80 kV. The cavity and the RF output coupler are identical as suggested for the industrial tube. All components are under fabrication. The experiment will allow investigation of RF generation and mode competition as well as of the efficiency of the RF output system and measurement of the amount of the internal stray radiation. In the case of step frequency tunable gyrotrons the possibility of multi-frequency operation of a gyrotron designed to oscillate in the $TE_{22.8}$ mode at 140 GHz, the $TE_{17.6}$ mode at 105 GHz and six other modes at frequencies in between is currently under investigation. The QO mode converter of the gyrotron consists of a dimpled-wall launcher and a beam forming mirror system. The first mirror is a large quasi-elliptical one, the second and third are phase correcting mirrors with a non-quadratic shape of the surface. A 140 mm diameter CVD-diamond disk is being developed at Element Six (formerly DeBeers Industrial Diamonds) for a full-size diamond Brewster window.

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