§30. Development of Gyrotrons as Radiation Sources for Diagnostics of LHD Plasma and Their Application to Scattering Measurements

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Over the years, several high performance devices ("Gyrotron FU series") have been designed, produced, tested and applied to a number of experimental studies. The gyrotrons from this series cover a wide frequency range up to 889 GHz. They are characterized by such advantageous features as amplitude and frequency modulation, high purity operation and stability of the output power.

Our gyrotron FU series consists of several high-power, frequency step-tunable radiation sources which operate in the millimeter and submillimeter wavelength region. Many distinguishing characteristics of these devices make them appropriate radiation sources for plasma diagnostics. In order to improve their operational performance as well as to extend their applicability to new scientific fields a series of problem-oriented studies have been pursued.

The Gyrotron FU IVA has achieved frequency tunability from 160 to 889 GHz and has been used in a high purity mode operation regime in several experiments. Operating on TE_{861} mode at the second harmonic of the cyclotron frequency the FU IVA delivers radiation with frequency 889 GHz, which is currently the highest value in the world.

The modulation of both amplitude and frequency of the generated radiation is essential for many far-infrared technologies. This two kinds of modulation have been succesfully achieved operating the Gyrotron FU IV, which is frequency tunable up to 847 GHz.

The amplitude of the output radiation generated in the Gyrotron FU IV has been stabilized by a feed-back control of the anode voltage of the magnetron injection gun.

High mode purity is necessary for an effective conversion of the gyrotron output into a gaussian beam. A new cavity, optimized in such a way as to ensure high purity mode operation has been designed at the University of Stuttgart and Forschungszentrum Karlsruhe. The cavity has just been installed in the Gyrotron FU VA. Now the final preparation for operation of this gyrotron in high purity mode regime is in progress.

We have begun construction of a quasi-optical gyrotron with Fabry-Perot resonator. One of the main advantages of the quasi-optical gyrotron over the conventional gyrotron is its continuous frequency tunability. For the present setup about ten percent tunability can be achieved around frequency near 90 GHz (fundamental operation) and 180 GHz (second harmonic). The gyrotron will be used for plasma diagnostics in the Large Helical Device.

The quasi-optical system consisting of a quasi-optical antenna and focusing mirrors can convert the gyrotron output into a gaussian-like beam. The antenna is used to convert the gyrotron output into a linearly-polarized beam. The design is significantly simplified using gaussian beam optics based on the assumption that in the far-field region the main beam produced by the quasi-optical antenna is similar to a bi-gaussian beam. This assumption is justified by the fact that the results obtained using the Huygens equation agree well with those using gaussian beam optics.

The system consists of a quasi-optical antenna, two focusing mirrors and a filter which removes the side lobes of the beam. This system is appropriate as a transmission line for frequency tunable gyrotrons operating at TE_{0n} and TE_{1n} modes. As an illustration of our approach, we present results which demonstrate the applicability of the developed system for conversion of the radiation generated by the Gyrotron FU IVA. The examples include conversion of four TE_{1n} mode outputs (TE_{12}, 170 GHz; TE_{13}, 271 GHz; TE_{14}, 372 GHz; TE_{15}, 472 GHz) into gaussian-like beams and three TE_{0n} modes (TE_{02}, 223 GHz; TE_{03}, 323 GHz; TE_{04}, 423 GHz) into bigaussian-like beams.

A quasi-optical system consisting of a quasi-optical antenna and two ellipsoidal mirrors can convert the gyrotron output (TE_{15} mode, 354 GHz) into a gaussian-like beam. The target gaussian beam is obtained by using a quasi optical antenna and two focusing mirrors and the beam size tunability is realized only by moving the second focusing mirror. The waist size of the beam produced is adjusted by moving a second ellipsoidal mirror. The second mirror with focal length of 520 mm offers a tunability range from 2.0 mm to 5.4 mm, while those with focal lengths of 1190 mm and 2390 mm are characterized by tunability ranges from 5.1 mm to 12.9 mm and from 12.0 mm to 25.1 mm, respectively.