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Experimental results of the 140 GHz, 1 MW long-pulse gyrotron for W7-X

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Abstract

Gyrotrons at high frequency with high output power are mainly developed for microwave heating and current drive in plasmas for thermonuclear fusion. For the stellarator Wendelstein 7-X now under construction at IPP Greifswald, Germany, a 10 MW ECRH system is foreseen. A 1 MW, 140 GHz long-pulse gyrotron has been designed, constructed and tested in an European collaboration between FZK Karlsruhe, CRPP Lausanne, IPF Suttgart, IPP Greifswald, CEA Cadarache and TED Vélizy.

The cylindrical cavity is designed for operating in the $TE_{28,8}$-mode. It is a standard tapered cavity with linear input downtaper and a non-linear uptaper. The diameter of the cylindrical part is 40.96 mm. The transitions between tapers and straight section are smoothly rounded to avoid mode conversion. The $TE_{28,8}$-cavity mode is transformed to a Gaussian $TEM_{0,0}$ output mode by a mode converter consisting of a rippled-wall waveguide launcher followed by a three mirror system. The output window uses a single, edge cooled CVD-diamond disk with an outer diameter of 106 mm, a window aperture of 88 mm and a thickness of 1.8 mm corresponding to four half wavelengths. The collector is at ground potential, and a depression voltage for energy recovery can be applied to the cavity and to the first two mirrors. Additional normal-conducting coils are employed to the collector in order to produce an axial magnetic field for sweeping the electron beam with a frequency of 7 Hz. A temperature limited magnetron injection gun without intermediate anode (diode type) is used.

In short pulse operation at the design current of 40 A an output power of 1 MW could be achieved for an accelerating voltage of 82 kV without depression voltage and with a depression voltage of 25 kV an output power of 1.15 MW at an accelerating voltage of 84 kV has been measured. For these values an efficiency of 49% was obtained. At constant accelerating voltages, the output power did not change up to depression voltages of 33 kV.

The output beam of the gyrotron is injected into an RF-tight microwave chamber which is equipped with two water-cooled mirrors directing the beam towards the 1 MW water load. The second mirror inside the microwave chamber contains a directional output coupler formed by a

row of holes in the mirror surface. A diode detector is connected to the directional coupler and the forward power can be determined once the signal has been calibrated. This was performed by calorimetric measurement of the RF-wave in short pulse measurements. The mode purity of the Gaussian beam was measured by a thin dielectric target plate placed at different positions across the RF beam. The measured beam distribution agrees very well with the theoretical predictions.

After some problems with the RF-load, long pulse operation was performed: The power measurements were done by the signal of the diode detector placed at the second mirror. The measured output power of the calorimetric RF-load normally shows values reduced by about 20%. Output powers of 1 MW could be achieved for 10s, and an energy as high as 90 MJ per pulse has been produced with an output power of 0.64 MW. The pulse lengths were mainly determined by the preset values, and due to lack of experimental time no attempt was made to increase the pulse length. Only for a 100 s pulse with 0.74 MW output power, a limitation was found due to a pressure increase beyond about 10^{-7}hPa.

The gyrotron was sent back to the manufacturer Thales Electron Devices for a visual inspection, and an improved tube will be built and delivered to Forschungszentrum Karlsruhe in February 2002.