PROGRESS ON GYROTRONS FOR ITER AND FUTURE THERMONUCLEAR FUSION REACTORS

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The prototype of the Japan 170 GHz ITER gyrotron holds the energy world record of 2.88 GJ (0.8 MW, 3600 s and 1 MW, 800 s) and the efficiency record of 57%. The Russian 170 GHz ITER prototype tube achieved 0.65 MW with a pulse duration of 800 s and 1.05 MW in 200 s pulses with an efficiency of 52%. The record parameters of the European megawatt-class 140 GHz gyrotron for the Stellarator Wendelstein W7-X are: 0.92 MW output power at 1800 s pulse duration, nearly 45% efficiency and 97.5% Gaussian mode purity. A similar 140 GHz CPI gyrotron has a somewhat lower efficiency. These gyrotrons employ a cylindrical cavity, a quasi-optical output coupler, a synthetic diamond window and a single-stage depressed collector (SDC) for energy recovery.

In order to keep the number of required gyrotrons and magnets as low as possible, to reduce the costs of the ITER 24 MW, 170 GHz ECH&CD system and to allow compact upper launchers for plasma stabilization, 2 MW mm-wave power per gyrotron tube is desirable. Cylindrical gyrotron cavities are not suitable for the 2 MW power regime because of high Ohmic wall losses and mode competition problems. However, in coaxial cavities the existence of the longitudinally corrugated inner conductor reduces the problem of mode competition, thus allowing one to use even higher order modes with lower Ohmic attenuation than in cylindrical cavities. Synthetic diamond windows with a transmission capability of 2 MW, CW are feasible. A 2 MW, CW, 170 GHz coaxial-cavity gyrotron for ECH&CD in ITER is under development in cooperation between European Research Institutions (EGYC*) and TED. At KIT the short-pulse (1 ms) pre-prototype tube delivered 2.2 MW at 30% efficiency (without SDC) with 96% Gaussian output mode purity. Design studies for a 4 MW 170 GHz coaxial-cavity gyrotron with two synthetic diamond output windows and two 2 MW mm-wave output beams for future fusion reactors are currently being performed at KIT.

The availability of sources with fast frequency tunability would permit the use of simple, fixed, non-steerable mirror antennas for local current drive experiments and plasma stabilization. IAP Nizhny Novgorod and GYCOM develop in collaboration with IPP Garching and KIT an industrial, multi-frequency 1 MW gyrotron with almost 50% efficiency (SDC). A four-frequency tube (105, 117, 127 and 140 GHz) delivered in 10s pulses 0.7 MW at 105 GHz and 0.9 MW at 140 GHz. After the installation of a broadband synthetic diamond window, this gyrotron will be operated also at the two intermediate frequencies.

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*EGYC is a collaboration among CRPP, Switzerland; KIT, Germany; HELLAS, Greece; CNR, Italy; ENEA, Italy