52394

Development of a High-Power, CW Gyrotron for the W7-X Stellarator

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High-frequency, high-power gyrotrons are needed for microwave heating (ECRH) and current drive (ECCD) in magnetically confined fusion plasmas [1]. The development of ECRH sources with CW capability is an especially important issue for stellarators. For the stellarator Wendelstein7-X now under construction in Greifswald, Germany, a 10 MW system is foreseen.

A European collaboration has been established to develop and build ten gyrotrons, each having an output power of 1 MW at 140 GHz for continuous wave operation (30 min). The major problems that have to be solved are Ohmic heating of the cavity surface, the power capability of the collector, and dielectric losses in the output window. To reduce the power density at the resonator surface, a high order volume mode is chosen as the operating mode (in this case the $TE_{28,8}$ mode at 140 GHz). The gyrotron has a diode-type magnetron injection gun, an improved beam tunnel designed to suppress spurious oscillations in that region, a resonator designed for high mode purity and low Ohmic losses, an optimized nonlinear uptaper, a very efficient internal quasi-optical mode convertor, a single-stage depressed collector and an edge-cooled, single-disk CVD-diamond window. Some details of the design are given in [2].

RF measurements at a pulse duration of a few milliseconds gave an output power of 1.15 MW at a beam current of 40 A and accelerating voltage of 84 kV. Operation with a depressed collector was possible up to decelerating voltages of 33 kV with no reduction in output power, and an efficiency of 49% was achieved. Long pulse operation of the gyrotron was possible with an output power of 1 MW and pulse length of 10 s with no signs of limitations caused by the tube. For this output power, it was possible to increase the efficiency from about 30% without a depressed collector to nearly 50% with the depressed collector. A pulse length of 140 s was achieved for an output power of 640 kW in the pre-prototype gyrotron. With a second, prototype version, output power of over 800 kW at pulse lengths of up to 180 s has been achieved.

References

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