Ongoing Developments for the KIT 2-MW 170-GHz Coaxial Cavity Gyrotron Prototype

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ABSTRACT

In order to satisfy the requirements of future thermonuclear plasma fusion power plants, KIT is working on advanced gyrotron concepts, such as the coaxial-cavity gyrotron technology. Experiments at KIT did demonstrate the superior performance of this technology by demonstrating an RF output power above 2.2 MW in short pulses (ms-range) at an operating frequency of 170 GHz. In comparison to the classic hollow-cavity gyrotron technology widely used in today's fusion gyrotrons the coaxial-cavity gyrotron technology offers reduced voltage depression and mode competition. That allows an operation in very high-order modes, and, correspondingly, leads to a significant higher RF output power. At KIT a modular type 170 GHz 2 MW short-pulse (ms) coaxial-cavity pre-prototype gyrotron operating at very short pulses up to a few milliseconds has been used to verify the superior performance of the coaxial-cavity gyrotron technology so far. Considering a CW operation of fusion gyrotrons in future, the main focus of KIT must be to verify the performance of the coaxial-cavity gyrotron at long pulses.

As a first step towards a coaxial-cavity gyrotron operating at CW, KIT is extending its short-pulse pre-prototype to pulse lengths up to 100 ms. This will allow the investigation of all performance parameters which are relevant for CW operation. The main issue for a long-pulse gyrotron is the introduction of a reliable cooling system due to the significant losses in the gyrotron. In particular, the beam tunnel, cavity, launcher, quasi optical mirror system, CVD diamond output window, and the collector have to be equipped with active cooling systems. One of the main advantages of the long-pulse gyrotron is the complete modularity. This has the advantage of easy implementation and testing of new subcomponents with advanced water cooling systems, material compositions and geometries. In line with the modularity, an independent cooling system for each component is necessary. This concept allows also the monitoring of the internal losses in each gyrotron component and of the final energy balance of the tube during long-pulse operation.

Recently, the first experimental campaign was successfully finalized. In this phase the new long-pulse gyrotron was validated in short-pulse operation in order to show the performance of the new gyrotron. During the experimental short-pulse test campaign, the KIT 170 GHz 2 MW coaxial-cavity long-pulse pre-prototype did show an excellent and very stable performance. The tube was operated at an acceleration voltage of up to U_c = 88 kV and an electron beam current of I_b = 75 A. At the nominal operating parameters an RF output power of 2.2 MW up to 2.5 ms pulse length has been achieved. An electronic (interaction) efficiency between the electron beam and the cavity electromagnetic field of ~33 % was achieved at nominal operating parameters.

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