Influence of Parasitic Backward Waves on Gyrotron Operation

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ABSTRACT

Gyrotrons are microwave tubes capable of delivering very high microwave power in the long-pulse and CW operation at frequencies above 100 GHz [1]. That is possible due to the fast wave working principle of gyrotrons which allows using cavities with a large electrical size (in the order of several cm) compared to the operating wavelength (in the order of a few mm).
Besides parasitic oscillations in the beam tunnel [2], the excitation of parasitic backward waves has shown to be a limiting factor in the operation of high power gyrotrons. Those instable unwanted modes are excited in the output-up-taper region of the gyrotron cavity. Since the cutoff radii of these backward waves are below the cutoff radius of the operating mode, they can penetrate further into the down-taper and, depending on the mode, even into the spacer region between the actual cavity and the beam tunnel. There, the interaction of the backward wave with the electron beam takes place even before the desired interaction in the cavity, where the operating mode is excited. This upstream parasitic interaction causes increased spreads of electron kinetic energy and pitch factor. The increased spread significantly reduces the interaction efficiency.
In order to find possible solutions to mitigate the influence of these parasitic, several parameter studies were carried out with the time-dependent, multi-mode, self-consistent interaction code EURIDICE [3] and the results were verified with a KIT-IHM in-house particle-in-cell code [4].
It can be shown that by reducing the electron pitch factor, the excitation of the backward wave is lowered. Similarly, a steeper magnetic field in the up-taper section reduces the generation of the parasitic wave. The most effective method, however, turns out to be a change of the down-taper and spacer region. The taper angle of the down-taper has to be increased, compared to the usual European designs [5]. If the down-taper angle is increased, the axial distance in the resonator, between the cut-off of the operating mode and the cut-off of the backward wave is reduced. Therefore, the axial range in which the electrons can be influenced by the parasitic backward wave is also reduced. By new designs of the spacer and down-taper section, the influence of these parasitic can be mitigated. This should be considered in the design of future cavities.

References

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