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Development of a metamaterial-based cavity beam current monitor

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Non-intrusive cavity beam diagnostic devices offer advantages such as high induced signal and sensitivity. The size of the resonant cavity is inversely related to its operating frequency, resulting in an increase in size at lower operating frequencies, thus limiting its applicability.
Therefore, exploring how to modify the cavity structure to regulate its internal electromagnetic field distribution and achieve a decrease in operating frequency has become a research topic of significant importance. In current cyclotron-based proton therapy devices, challenges arise from low beam repetition rates and weak intensities. These characteristics make traditional cavity beam diagnostics ineffective, resulting in monitoring blind spots during treatment. To tackle this challenge, this paper introduces a metamaterial-loaded cavity beam current monitor (BCM). Electromagnetic simulations reveal that this approach significantly reduces the size of the cavity under low-frequency operational settings. Moreover, this technique addresses the problem of high energy loss observed in conventional dielectric-loaded cavity BCM, effectively improving sensitivity. The all-metal metamaterial structure also circumvents difficulties associated with processing. This innovative design presents a fresh avenue for exploring the development of compact cavity beam diagnostics suitable for low-frequency operational environments.

Footnotes

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