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The study of a tunable double-ring permanent magnet focusing device for low-energy electron acceleration

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This study addresses the insufficient focusing force in solenoid focusing devices for low-energy electron accelerators, which leads to beam spot precision issues. A tunable double-ring permanent magnet focusing device based on the Halbach structure is proposed. The use of octagonal magnets replaces traditional sector magnets, avoiding the issue of differing magnetization directions. The effects of the radius of the octagonal magnets, aperture, mechanical length, and the rotation angles of the inner and outer magnetic rings on the magnetic field gradient and higher-order harmonics are analyzed. Optimal structural parameters lead to a double-ring magnet structure with a good field radius greater than 20 mm and higher-order harmonic content below 1.5%. By rotating the magnetic rings, a continuous adjustable magnetic gradient from 0.1 T to 1.5 T is achieved. The effective length and magnetic gradient of each lens unit are iterated using TraceWin software, successfully reducing the beam spot size of a 60 kV/10 mA electron beam from 4 mm to 500 μm. The focusing performance was verified through CST software simulations, providing an effective solution for low-energy electron accelerators.

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