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Plasma Density Shaping for Enhanced Electron Beam Control and Brilliant X-ray Generation in Laser Wakefield Acceleration

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Energy gain in laser wakefield accelerators is limited by dephasing, and the resulting electron beams often exhibit high divergence, posing challenges for transport and applications. We experimentally demonstrate that tailoring the plasma density profile can mitigate both limitations. Using shock-assisted ionization injection, we generate quasi-monoenergetic 100 MeV electron bunches. A subsequent, independently tunable plasma density region enables controlled energy enhancement or divergence reduction, yielding a 25% energy boost and 40% divergence reduction. Furthermore, electron bunches focused within a dense, passive plasma lens emit X-ray pulses with divergences approaching the incoherent limit. This facilitates the development of highly collimated, brilliant, few-femtosecond X-ray sources for ultrafast science.

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