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Beam optics analysis by visible cameras applied for the first time to a large-scale multi-beamlet configuration in the ITER prototype source

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The production of high energy neutral hydrogen/deuterium beams (0.87MeV/1MeV) with more than 90% homogeneity and extremely low divergence (<7mrad) is one of the biggest challenges for the realization of the ITER Neutral Beam Injector system.
To reach this goal, the ITER-like radio-frequency negative ion source, SPIDER, is in operation at the Neutral Beam Test Facility in Padua since 2018.
For the first time since the beginning of the operation, experiments are now carried out by simultaneously extracting up to 312 beamlets from a single beam segment (out of the total 1280 beamlets of the entire area).
Among the various diagnostics available to investigate beam features, SPIDER visible tomography, composed of 15 2D visible cameras surrounding the vacuum vessel, has already proven to be a powerful non-invasive diagnostic tool for the characterization of the beam in configurations with isolated extracted beamlets.
In the present work, beam optics is investigated by means of visible cameras positioned on the top of the SPIDER vessel, looking vertically through the beam. Even with an entire segment open, these cameras are capable of distinguishing columns of superimposed beamlets within the same beamlet group.
In this way, the width of the beamlets aligned with the camera line of sight is accurately estimated at different positions along the beam propagation direction through a Gaussian fitting procedure. The width is then used to evaluate the beamlet divergence.
The analysis method is here presented and the dependence of divergence on source parameters, such as radio-frequency power, gas pressure, and the magnetic filter field, is explored through dedicated perveance scans in different beam source configurations.
Results by visible cameras are compared with the data obtained from other beam diagnostics.

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