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New density profile reconstruction method from the time delay in O and X mode reflectometry

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Profile reflectometers are ubiquitous on magnetic fusion devices. For X-mode reflectometry, the standard method for density reconstruction has been the Bottollier-Curtet method [1] or its derivatives [2]. All these methods reconstruct recursively the density profile from the phase. However, the phase is an ill-defined parameter: the phase extraction is highly non-linear becoming very noisy at low signal to noise ratio or with multiple components; the total phase shift φ is not directly accessible but wrapped into $\varphi \in [-\pi, \pi]$ requiring unwrapping from the plasma edge a to the cutoff layer R_c. On the other hand, the time delay $\tau = \frac{1}{2\pi}\frac{\partial \varphi}{\partial F}$ is an instantaneous physical quantity: directly measured in pulse radar reflectometry or proportional to the beat frequency f_b with $f_b = \frac{1}{2\pi}\frac{\partial \varphi}{\partial t} = \frac{\partial F}{\partial t}\tau$ in swept reflectometry system.

We have developed a new method to reconstruct the density profile from the time delay. It overcomes the divergence of the WKB approximation integral at the cut-off layer R_c, $\tau(F) = \int_a^{R_c(F)} \frac{dR}{v_g(R,F)}$. The method has been developed for X and O mode polarizations. It can be applied to compute the group delay for synthetic diagnostic applications with known radial profiles of density, magnetic field and temperature.

For the direct profile reconstruction, the best approximation to evaluate the last part of the time delay integral $I = \int_{R_c(F_i)}^{R_c(F_{i+1})} \frac{dR}{v_g(R,F_{i+1})}$ leads to a second order equation in $\Delta R = R_c(F_{i+1}) - R_c(F_i)$. The method has been used to fasten the profile inversion in preparation for real-time reflectometry measurements [3].

[1] H. Bottllier-Curtet and G. Ichtchenko, *Review of Scientific Instruments* **58** (1987) 539.

[2] R.B.Morales *et al.*, *Plasma Sci. Technol.* **22** (2020) 064005.

[3] M.Carrard *et al.*, this conference.

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