XTOP 2026
16th Conference on High-Resolution X-Ray Diffraction and Imaging
21–25 September 2026, Karlsruhe, Germany

VIII: Theory, AI & Algorithms
Thursday, 24.09.2026 · 11:00-12:30

Sensitivity maximization in XRR and HRHRD by Fisher information: search for the most informative scan points

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Presentation type: Oral **Presentation time:** 11:45-12:00

Measurement of an XRR or HRXRD profile is a time-consuming procedure when a laboratory diffractometer is used. It can represent a bottleneck for a production pipeline in semiconductor industry or overextend the sample processing time in investigation of challenging samples with complicated interference patterns, when high-SNR dataset is required. Typically, an XRR or HRXRD profile is acquired by scanning over certain range of angles with the total acquisition time divided equally between all the scan points [1-3]. However, not all the points are equally valuable for retrieval of the information about the investigated sample. For example, the vicinity of the layer's Bragg peak in an HRXRD profile is likely to contain most of the information about the lattice cell of that layer. In an XRR profile, smaller angles correspond to electron density and surface roughness of the topmost layer, while higher angles with interference fringes are useful for analysis of layer thicknesses [1-4]. Intuitively, a time-efficient approach consists in selecting a small number of the most informative scan points and allocating the available measurement time for them.

From that perspective, a number of practical questions arise. How can one quantify the informativity of a particular measurement scenario? How many scan points (and which ones) are optimal for a specific sample model? How the measurement time should be split between the points? Does inaccurate prior information about the sample hinder the measurement optimization? To give systematic and algorithmizable answers to those questions, we use Fisher information – a powerful mathematical tool suitable for quantification of data informativity and optimization of measurements [5]. First, we illustrate the idea by comparing informativity of individual profile points for single-parameter estimation problems and reproduce the known relation between the sample layers' parameters and the XRR or HRXRD profile parts mostly influenced by them. Next, we develop the measurement optimization methodology for simultaneous inference of multiple sample parameters and apply it to several XRR and HRXRD problems with complex interference patterns. Finally, the influence of the inaccurate prior knowledge about the sample on the appropriateness of the optimized measurement angles is analyzed and the methodology is modified accordingly.

References

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