Optimization of X-Ray Capillary Optic Arrays for Mammography

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It has been shown that linearly tapered polycapillary optics significantly improve mammographic image quality through increased resolution and reduced x-ray scatterer. These characteristics result from the phenomenon of total external reflection. For practical clinical application, multi-element arrays with a common focal point will be required.

A prototype array, with each optic having a diameter of approximately 1 cm, was investigated. This study quantified the contributing factors to the multi-element array MTF and investigated methods to determine optimal parameters for a practical design. An idea optic, with MTF of 100%, would increase system MTF by the magnification ratio. Non-ideal contributors to optic MTF have been quantified. Contributions to optic MTF (with values given at 5 cycle/mm- the Nyquist limit of the detector) included: misalignment between optics, capillary channel size, curvature, optic twist, and vibration. Measurements and modelling found that misalignment up to 1 milliradiation reduced MTF by less than 10%. Channel diameter of 52 microns and 85 microns reduced MTF by 9% to 20% and provided an optimal tradeoff between transmission and MTF. Simple measures can be undertaken to assure acceptable limits of optic curvature. Misalignment due to curvature of less than 50micron results in no more than a 5% effect on MTF, as described by modelling. Optic twist, if not properly controlled, could have a substantial effect on MTF. However, if held to within 1 degree, modelling suggests that effect is less than 15%. With all of these factors considered, multi-element array MTF is only slightly reduced and system MTF is significantly increased. Since factors affecting performance have been identified, this will make it possible to improve the imaging characteristics of individuals optics and multi-element arrays.

Conventional DQE formalism does not account for the effects of scatter. Yet, removal of scatter can significantely improve image quality. Empirical and analytical methods demonstrating the

effect of scatter on DQE were developed to more accurately represent the clinical performance of the prototype. Results with the prototype demonstrate a 50% increase in DQE at 4 cycle/mm.

Predictions show that incorporating 25micron channel diameter optics into a commercially available full-field mammographic slot-scanning system might increase the Nyquist limit to approximately 15 cycle/mm and have a 5% MTF at nearly 15 cycle/mm. Optics with a magnification of 1.33 could double at the DQE at 10 cycle/mm. Increasing the magnificantion to 1.5 provides an even greater increase in DQE.