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Developing an X-ray Imaging Strategy

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At its simplest level, an X-ray image is a two dimensional array of pixels, and each pixel contains a vector of intensities across X-ray energy channels. However, given the relatively simplistic definition of an X-ray image, one might believe that the selection of array size and energy range is arbitrary. While it is true that these parameters are only constrained by the limits of hard drive space, practice has shown that they are actually constrained by time, resolution of the excitation beam and the composition of the sample. When trace element detection limits are of interest, acquisition parameters such as dwell time, oversampling and beam diameter have to be carefully balanced in order to achieve the intended result in a reasonable period of time. Ultimately, X-ray images are constrained by the goals of the analyst, and one set of standard imaging parameters is not sufficient for all experiments.

An X-ray imaging strategy is a method for optimizing the time and instrument parameters required to collect an X-ray map given the goal of the analysis. While X-ray mapping strategies are probably not needed for fast “3 minute egg” style maps, they become extremely important for stationary beam (stage scanning) X-ray imaging. In the case of stage scanned beams (whether electron or X-ray), imaging is commonly done on the order of 8 h to 24 h, especially where large area (>10 cm^2) mapping is considered. Slight variation on the pixel spacing or dwell time can produce changes on the order of hours in large stage maps.

Shown on the next page, Figures 1 and 2 provide an example of the geometric considerations for X-ray imaging. While intuition may suggest that the best way to image a sample is to allow the pixel spacing to be equal to the radius of the beam, such pixel spacing creates tremendous overlap between the pixels. This means that each pixel is actually an area average of 5 pixels. Conversely, when the pixel spacing is twice the radius, a significant portion of the sample will not be irradiated. Geometric analysis shows that, given radius = R (arbitrary units), when the pixel spacing is approximately 1.4*R, the entire sample is irradiated, and the influence of surrounding pixels is minimized. In addition to geometric considerations, statistical considerations, such as minimum determination limits, have similar relationships allowing the user to select a series of optimum parameters.

This talk will focus on the measurements and calibrations necessary to develop a mapping strategy. It will provide examples of different mapping strategies applied to the same sample, and show how simulation can be used to predict the influence of the parameters in the mapping strategy. It will focus on some common goals of analysis, including particle searching, trace element imaging and large area "road mapping".

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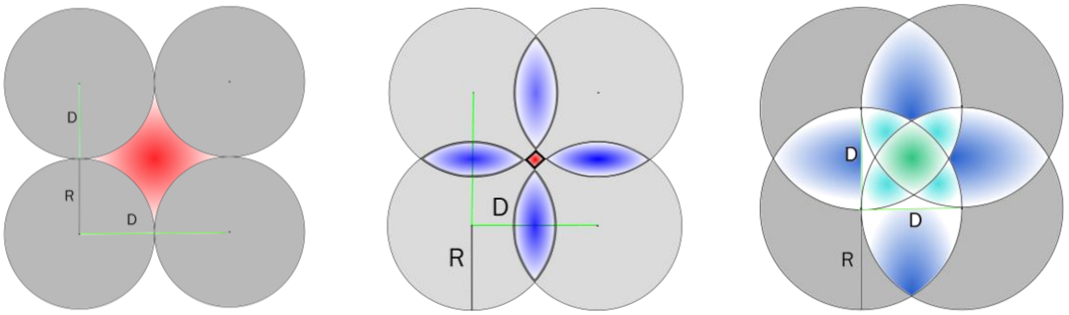

Figure 1: Graphic Showing General Beam Overlap Cases

The figure shows the three cases for general beam overlap. The first case (left) has no overlap between the circles, and the area marked in red is not irradiated by the beam. In this instance, the distance between the centers is equal to twice the radius. When the distance between the centers is equal to the radius, the third case (right) is the result. In the intermediate case, where the distance is between R and 2R, areas of overlap must occur, but the area not irradiated (shown again in red) will approach zero.

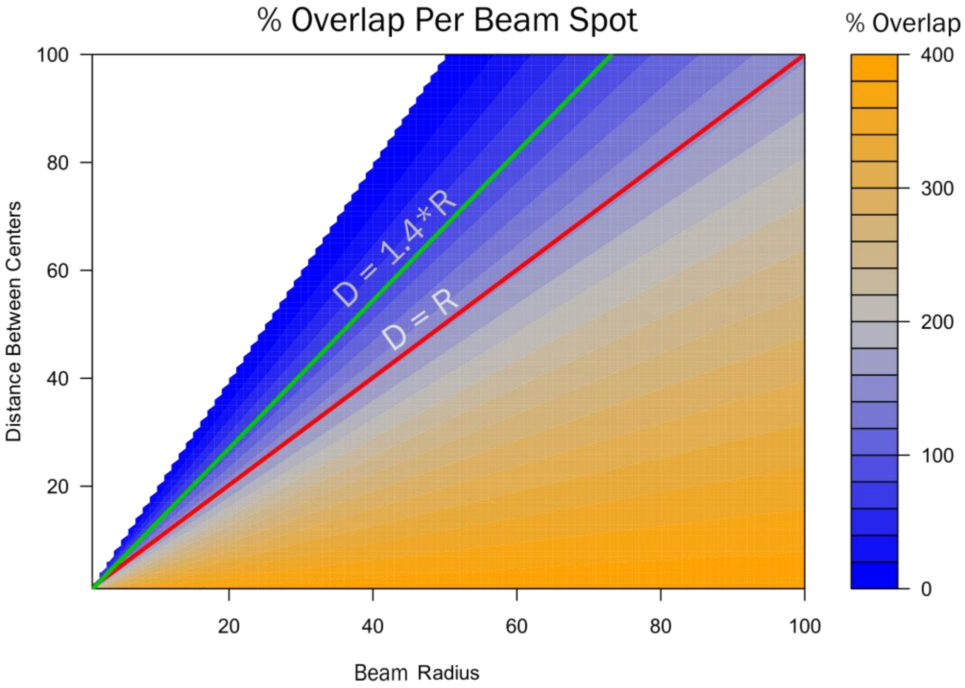

Figure 2: Plot of the % Overlap Area Per Beam Spot

Each beam spot, shown in the cases 2 and 3, overlaps in 4 regions around the circle. The ratio of the overlapped area to the area of a single spot is plotted. When the distance between centers is larger than 2R, no overlap occurs (white region), and the area not irradiated increases from $0.86R^2$. The red line shows the D = R line, also known as case 3. Shown as a green line, the 1.4R case represents a unique solution of case 2 where the area not irradiated by the beam is close to zero. Geometric considerations for imaging are important for particle searching and high resolution imaging, and this chart can be used to determine optimal pixel spacing.