Self-Calibration with Fiducial Gratings

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The goal of this work is to develop a novel self-calibration technique which utilizes a fiducial grating instead of an array of discrete marks. The impact of this work will be seen in the advanced metrology, electron-beam lithography (EBL), and semiconductor industries, where increasingly smaller stage navigation tolerances are required and multi-column systems are being developed.

Traditional self-calibration techniques use multiple measurements of an array of marks on a test plate to simultaneously calculate the stage error, the mark error (artifact error), and the translation and rotation of the test plate for each measurement. This approach was first introduced by Raugh in the mid-1980s.[1] Ye followed this work with a more computationally tractable and noise immune approach.[2] While effective, the self-calibration technique using an array of marks has many downsides such as the inclusion of mark error, the inability to adjust sample location without fabricating a new artifact or modifying the existing artifact, and the inability to simultaneously self-calibrate multiple columns when used on a multi-column system.

To address these limitations, the authors propose a novel self-calibration technique using a fiducial grating which provides several advantages including:

- Reduction in artifact error due to a higher accuracy in fiducial grating fabrication compared to discrete marks and fiducial grids.
- Improved noise tolerance due to the use of phase measurement which averages the stage position over many periods of the grating.
- Ability to simultaneously self-calibrate multiple columns when used in a multi-column system due to the grating being identical across the entire metrology artifact.

Current results include simulation of the proposed self-calibration technique for a single-column system as seen in Figures 1 and 2. Future work includes completing the self-calibration process on an interferometer equipped single-column system using the experimental metrology grating wafer seen in Figure 3; and adapting the technique for simultaneous self-calibration of multiple columns on a multi-column system.

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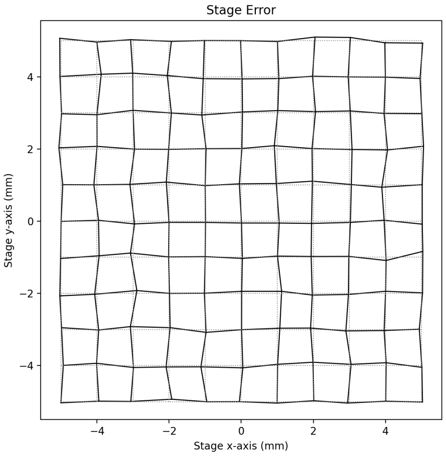
[1] M. R. Raugh, "Absolute two-dimensional sub-micron metrology for electron beam lithography: A calibration theory with applications," *Precision Engineering*, vol. 7, no. 1, pp. 3–13, Jan. 1, 1985, issn: 0141-6359. doi: 10.1016/0141-6359(85)90072-8.

[2] J. Ye, M. Takac, C. N. Berglund, G. Owen, and R. F. Pease, "An exact algorithm for self-calibration of two-dimensional precision metrology stages," *Precision Engineering*, vol. 20, no. 1, pp. 16–32, Jan. 1, 1997, issn: 0141-6359. doi: 10.1016/S0141-6359(97)00005-6.



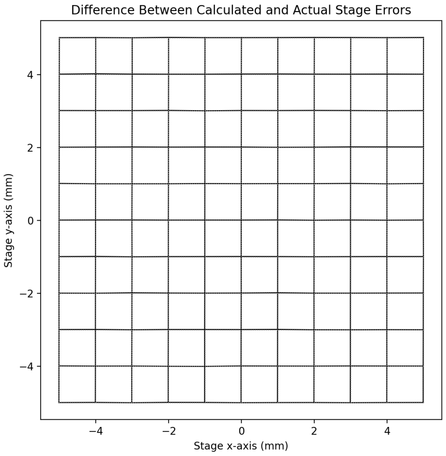


Figure 1 (left): Stage Error: Randomly generated stage error for 121 sample sites over a 10x10 mm area with sample sites spaced at 1 mm. The dotted line depicts an errorless stage while the solid line depicts a stage with the randomly generated error.

Figure 2 (right): Difference Between Calculated and Actual Stage Error: Stage error calculated with the novel self-calibration using a fiducial grating technique of the randomly generated stage error from Figure 1. Calculating the stage error involves taking 3 images at each sample site with the grating rotated 0, 45, and 90 degrees.

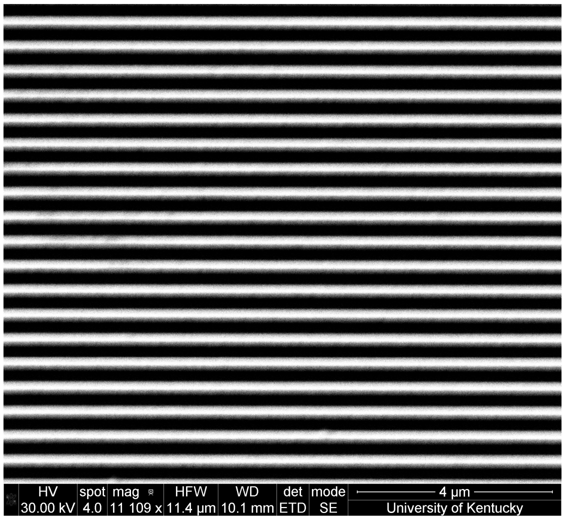


Figure 3: Metrology Grating Wafer: 10x10 um image of metrology grating wafer with a pitch of 500 nm. Image taken on FEI Quanta 250 ESEM paired with Raith Elphy EBL system at the University of Kentucky Electron Microscopy and Materials Characterization Core.