## 11. Interference Lithography for Patterning Variable-Period Gratings

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Scanning-beam interference lithography (SBIL) patterns large-area, linear, low-phase-distortion gratings with a pair of small diameter (millimeter size) phase-locked laser beams. We are developing a new system that generalizes the concept of phase-locked scanning beams for patterning continuously varying (chirped or quasi-periodic) patterns. These structures can subsequently be used to fabricate chirped x-ray reflection gratings for astronomical imaging applications, chirped fiber Bragg gratings for time-delay or spectral filtering applications, and/or diffractive optical elements.

Figure 1 shows the experimental diagram of the variable-period scanning-beam-interference lithography (VP-SBIL) system. For controlling the grating period and orientation, the system employs dual-axis picomotor-driven gimbal mirrors to produce symmetric deflections of a pair of interfering beams around the optical axis without translation. Two objective plano-convex lenses (f# = 4.25, 2.12) are used in a 4-f optical configuration. Such a lens system allows the conjugate points of beam deflection (on mirrors) to overlap at the focal plane of the second objective lens. The spot size of image overlap is reduced to half the beam diameter as the ratio of focal lengths $f_2/f_1=0.5$. This relaxes the maximum period variation ($\Delta\Lambda$) constraint over the image diameter (D) that requires $\Delta\Lambda/\Lambda \ll \Lambda/D$ where $\Lambda$ is the grating period.

To attain phase stability during grating patterning, homodyne fringe locking is adopted using an imaging detector, analog fringe-locker and a piezo-actuated mirror in closed-loop. In the present experimental configuration, two-axis beam rotation can generate any fringe orientation. However, variation in grating period (2 μm to 1000 μm) is limited by the range of deflection produced by the gimbal mirrors (± 10º) and by the numerical aperture (NA) of the lens system. Using position-sensitive detectors with an appropriate imaging and Fourier lens configuration, closed-loop beam steering is implemented to vary the grating period and orientation in a predetermined fashion. Typical requirements for x-ray reflection grating fabrication are $\Lambda_{ave}\sim 2$ μm and chirp factor $\Delta\Lambda/\Lambda \sim 5\%$.

Fig. 2 shows two grating images of period 2.0 μm and 4.0 μm obtained on a static substrate by changing the angle between the beams using the picomotor-controlled gimbal mirrors. Line uniformity in the images indicates minimal fringe distortion over the entire beam overlap. The picomotors can be constantly driven to write large-area gratings with continuously varying period and orientation on a substrate mounted to a precision X-Y stage. The piezo-actuated picomotors (which produce displacement jitter and exhibit low bandwidth operation) will be subsequently replaced by voice coil-actuated fast steering mirrors.

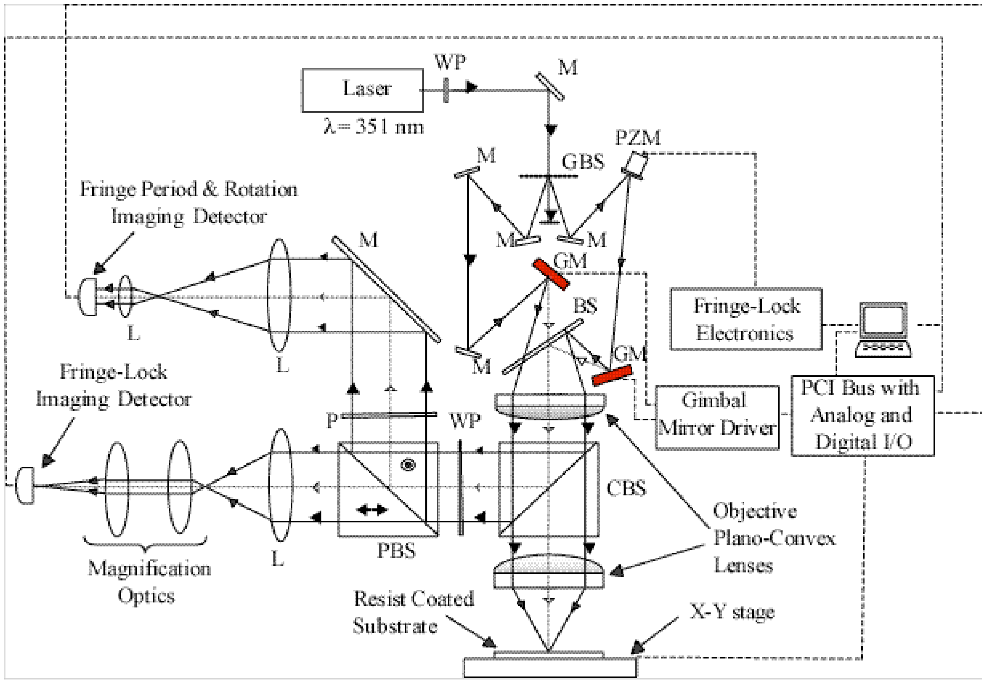


***Figure 1.*** *Experimental diagram of variable-period scanning-beam-interference lithography system. M: mirror, L: lens, P: polarizer, GM: gimbal mirror, WP: wave plate, BS: beam splitter, PZM piezo-actuated mirror, GBS: grating BS, CBS: cubic BS, PBS: polarizing BS.*

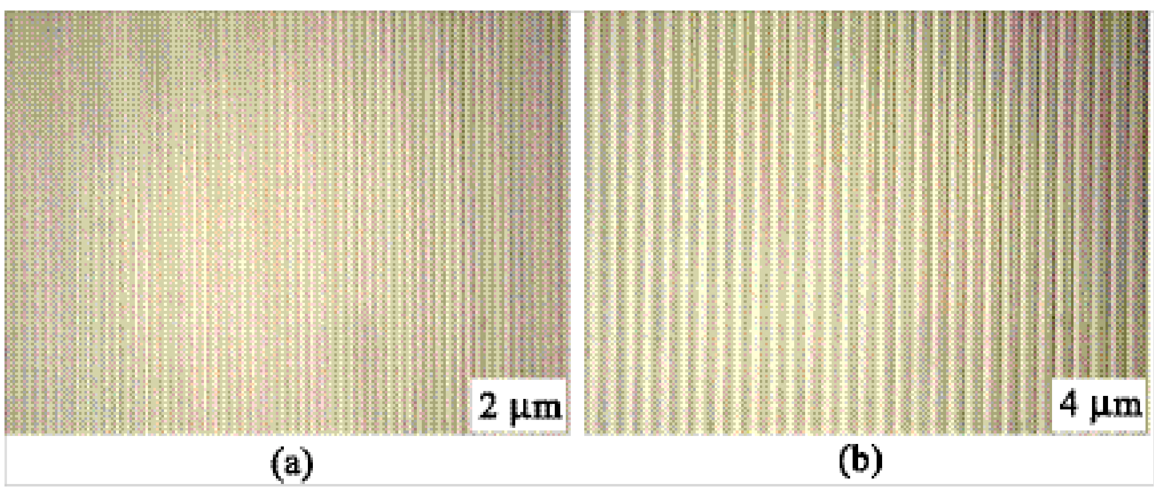


***Figure 2.*** *Optical micrographs of gratings written by VP-SBIL with periods (a) 2.0 μm and (b) 4.0 μm.*