次世代観測装置用の新しい回折格子の開発状況 II

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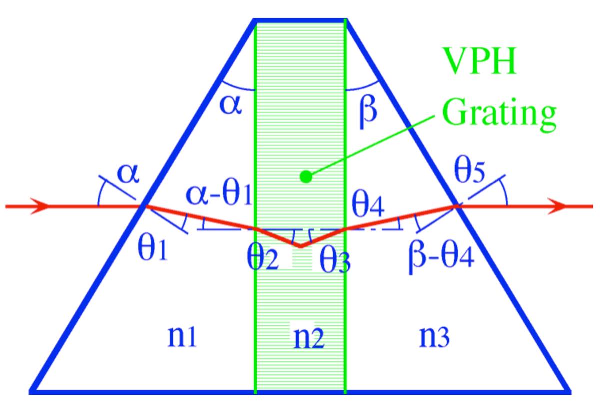
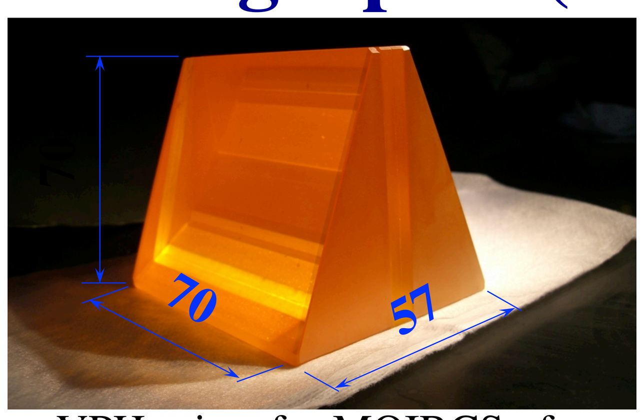
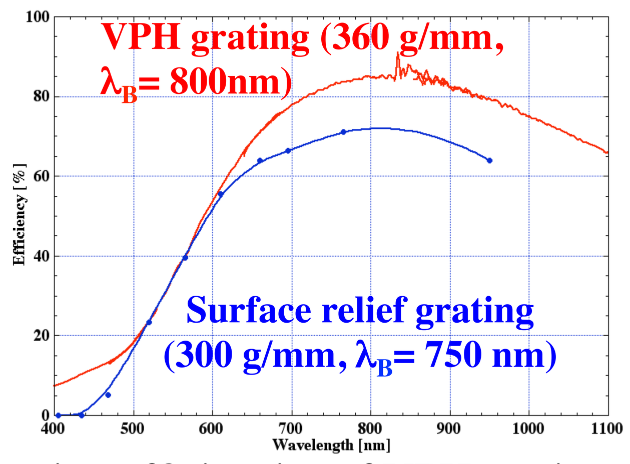
Volume Phase Holographic (VPH) grating



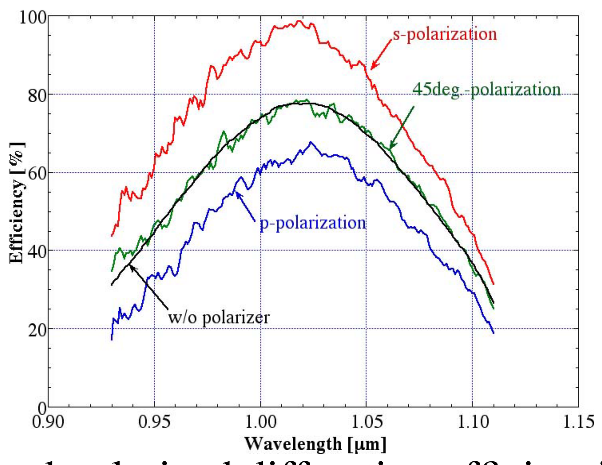


VPH grism for MOIRCS of 8.2m Subaru Telescope.

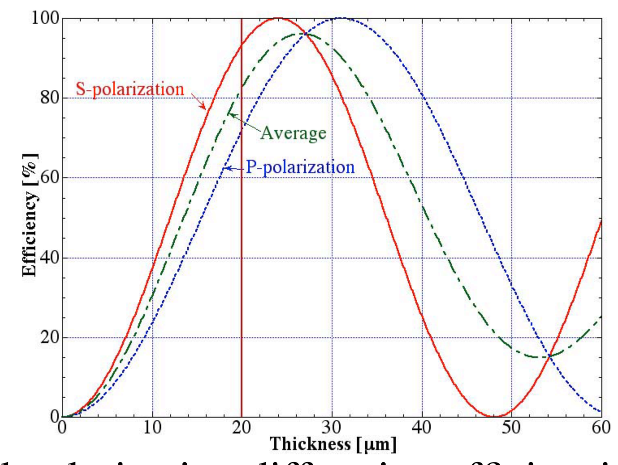


Diffraction efficiencies of VPH grating and surface relief grating for moderate dispersion.

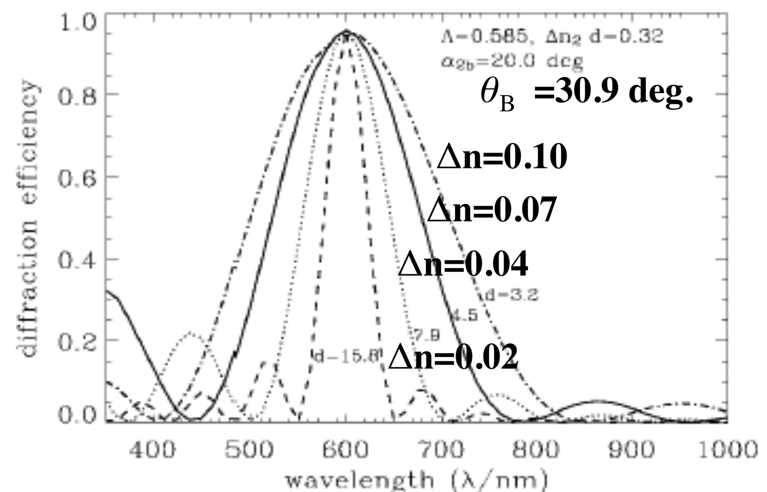
$$\eta_S = \sin^2\left\{\frac{\pi(n_{max}-n_{min})t}{\Lambda(n_{max}+n_{min})\sin 2\theta_B}\right\} \quad \eta_P = \sin^2\left\{\frac{\pi(n_{max}-n_{min})t\cos 2\theta_B}{\Lambda(n_{max}+n_{min})\sin 2\theta_B}\right\}$$



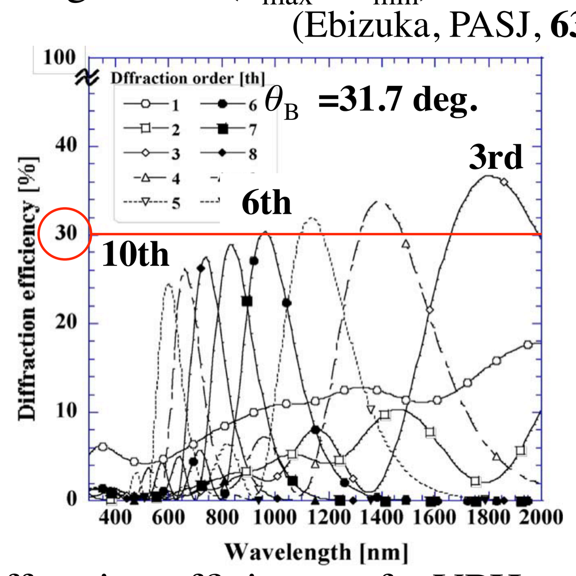
Measured polarized diffraction efficiencies of VPH grating. $n_{ave}= (n_{max} - n_{min})/2 = 1.53$, $\Lambda = 0.984$ μm, $t = 20$ μm, θ_B 32.7° @1.02 μm.



Calculated polarization diffraction efficiencies vs. t of VPH grating. $\Delta n = (n_{max} - n_{min})/2 = 0.017$.
(Ebizuka, PASJ, **63**, 2011)

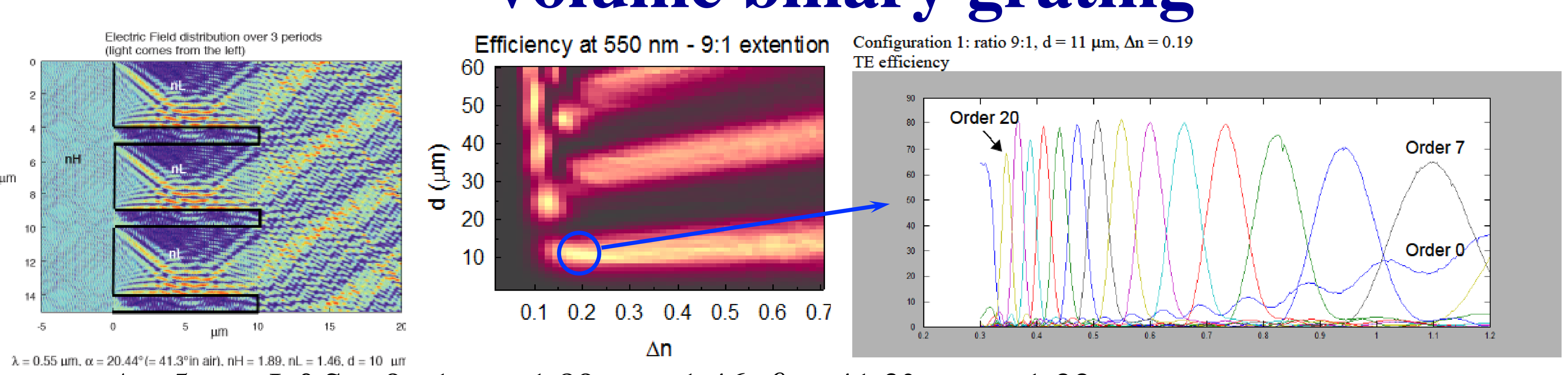


Band width becomes narrow toward large diffraction angle because semi-amplitude of index modulation (Δn) of dichromated gelatin is up to 0.1. (Baldry, PASP **116**, 2004)



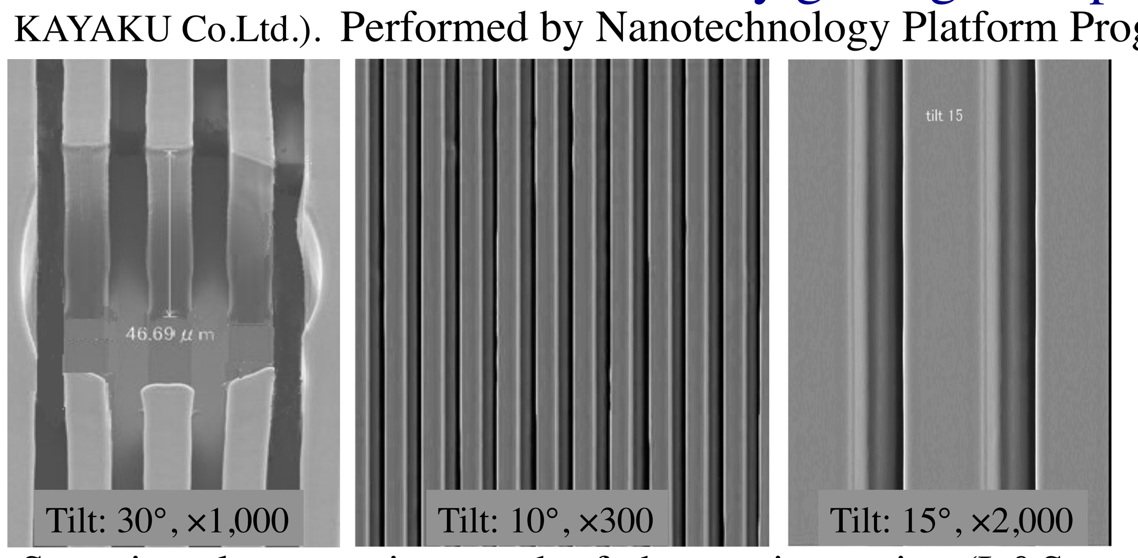
Diffraction efficiency of a VPH grating decreases toward higher orders.
(Oka, SPIE **5290**, 2004)

Volume binary grating

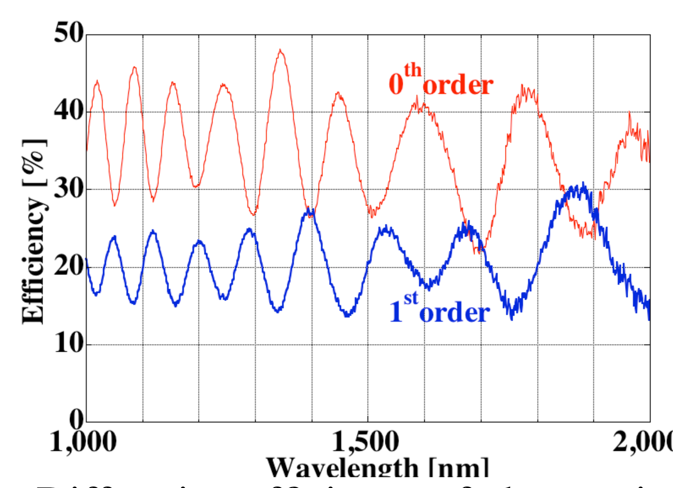


$\Lambda = 5$μm, L&S = 9 : 1, n_H=1.89, n_L= 1.46, θ_B= 41.3°, w:t = 1:22. (Bianco, SPIE, **8450**, 2012)

Test fabrication of volume binary grating with photoresist (KMPR1000, NIPPON KAYAKU Co.Ltd.). Performed by Nanotechnology Platform Program of Toyoda Technological Institute.

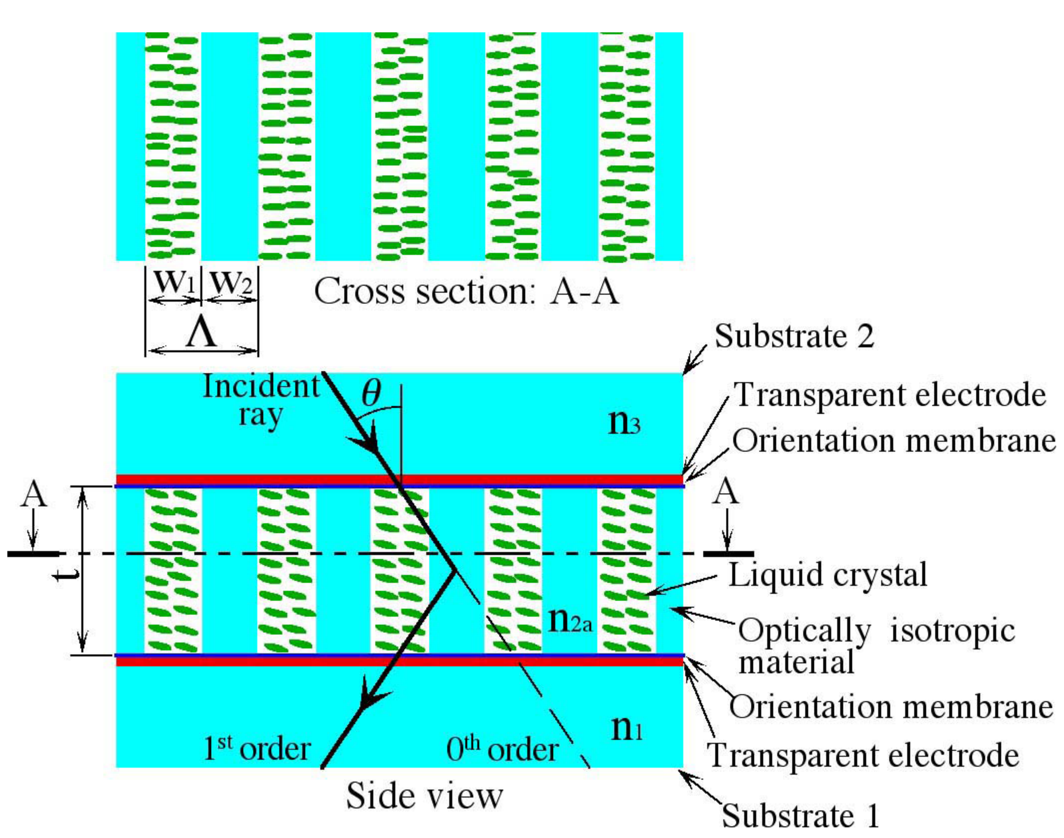


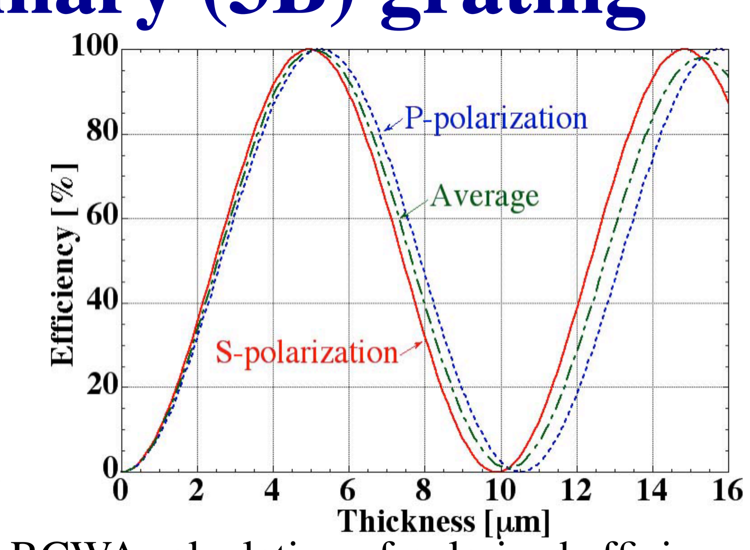
Scanning electron micrograph of photoresist grating (L&S: 10:10μm), groove depth: 46.7/sin30 = 93.4μm (left).



Diffraction efficiency of photoresist grating (L&S: 8:12μm, t~50μm).

Birefringence Bragg binary (3B) grating

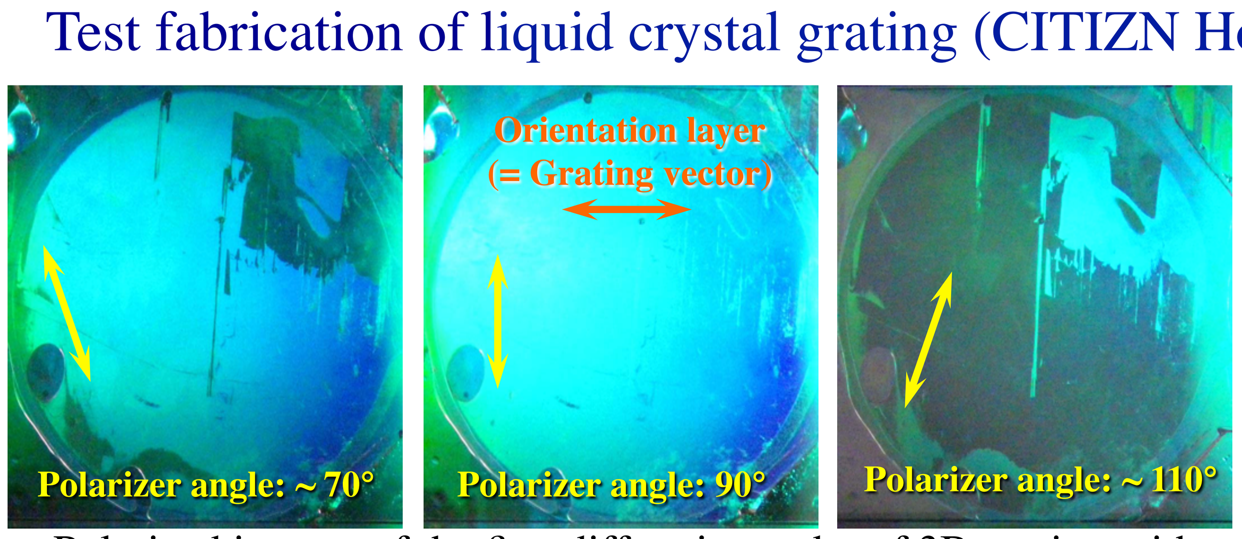




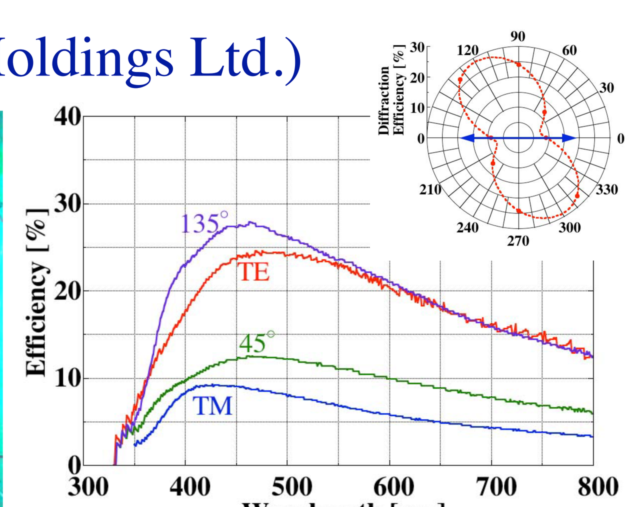
RCWA calculation of polarized efficiency of 3B grating. n_{2a} = 1.460, n_{Smax} = 1.544, n_{Pmax} = 1.598, Λ = 0.424 μm, λ = 0.6 μm, θ_B = 45° t = 5 μm, $w:t$ = 1:23.6. (Ebizuka, SPIE 8450, 2012)

n_{2a}=1.34*, n_S = 1.54, n_P=1.74, $w:t$ ~ 1:10?
* Cytop or UFR@AGC

Test fabrication of liquid crystal grating (CITIZN Holdings Ltd.)

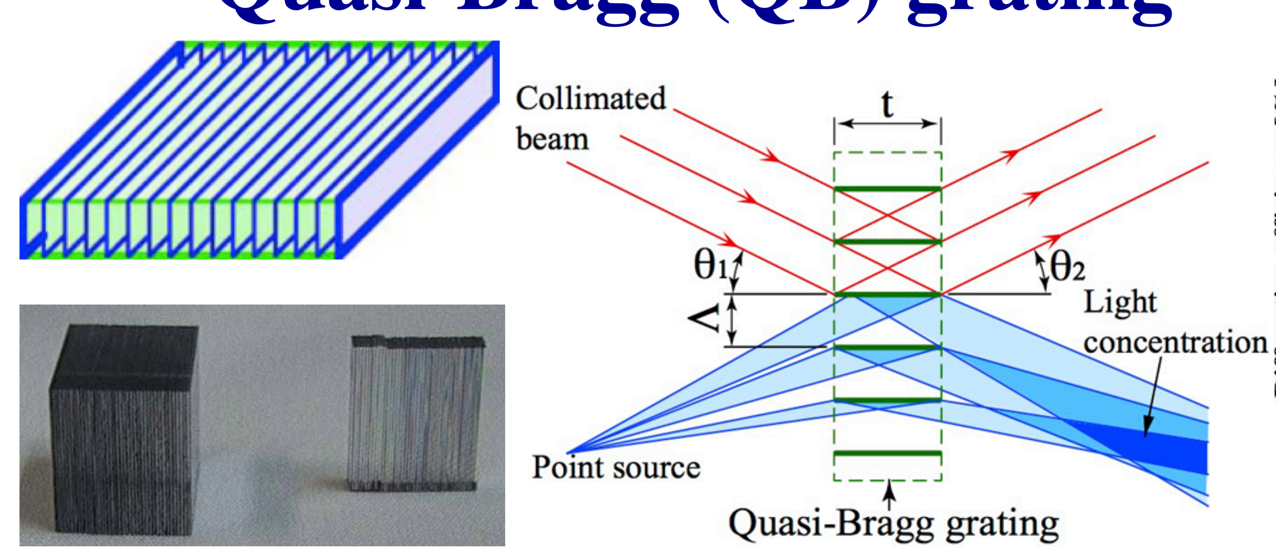


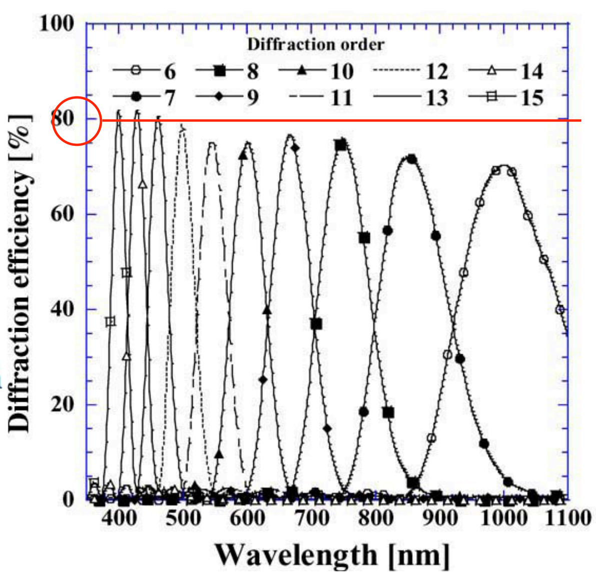
Polarized images of the first diffraction order of 3B grating with liquid crystal.



Polarized diffraction efficiencies of 3B grating with liquid crystal. (L&S: 1:1μm, t=1μm).

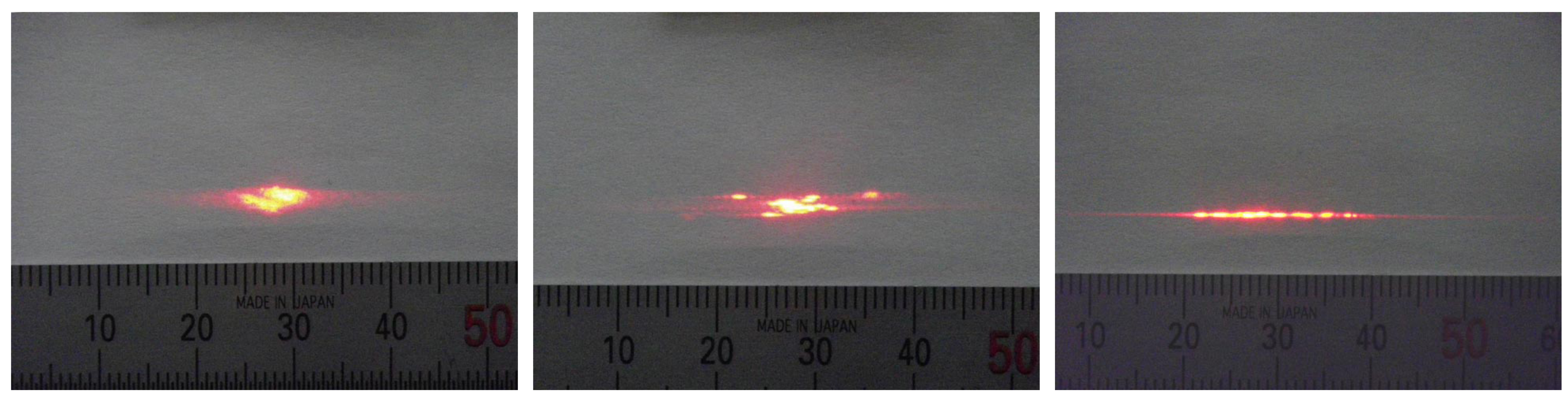
Quasi-Bragg (QB) grating





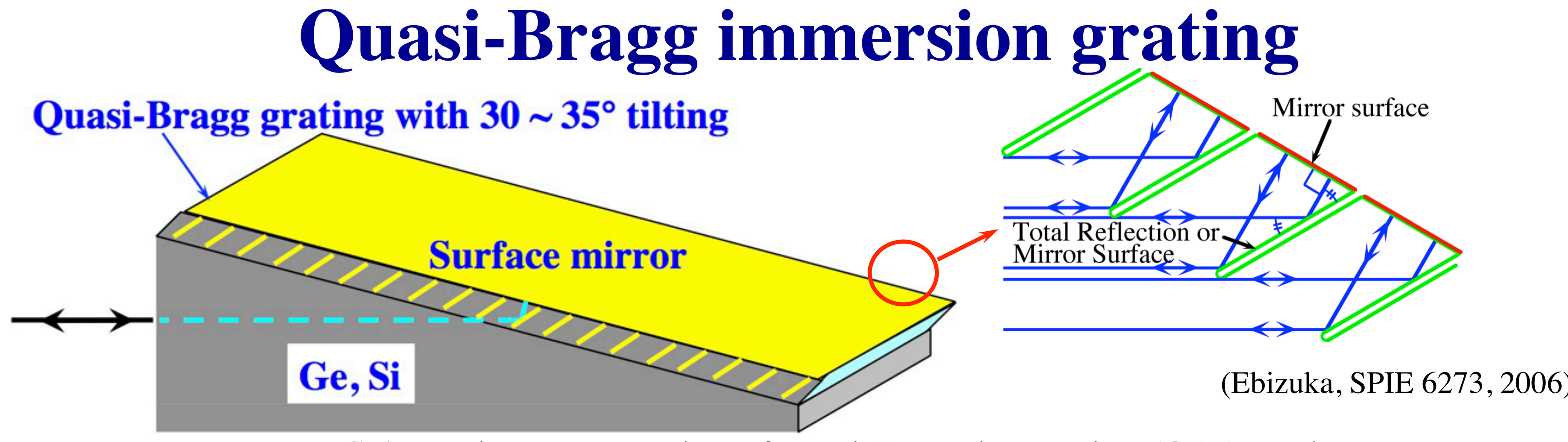
Schematic representation of quasi-Bragg (QB) grating (left above & center). Fabricated QB grating, silica glass substrates laminated by adhesive mixed with glass beads (left below). Diffraction efficiency of QB grating (right, Oka, SPIE 5290, 2004).

We are planning to perform new fabrication method which mirror plates laminated by pressure fusion of gold films.



Diffracted beam images of far field of QB gratings. Silica glass substrates laminated by adhesive mixed with glass beads (left). Silica glass substrates laminated by pressure fusion of gold (center & right).

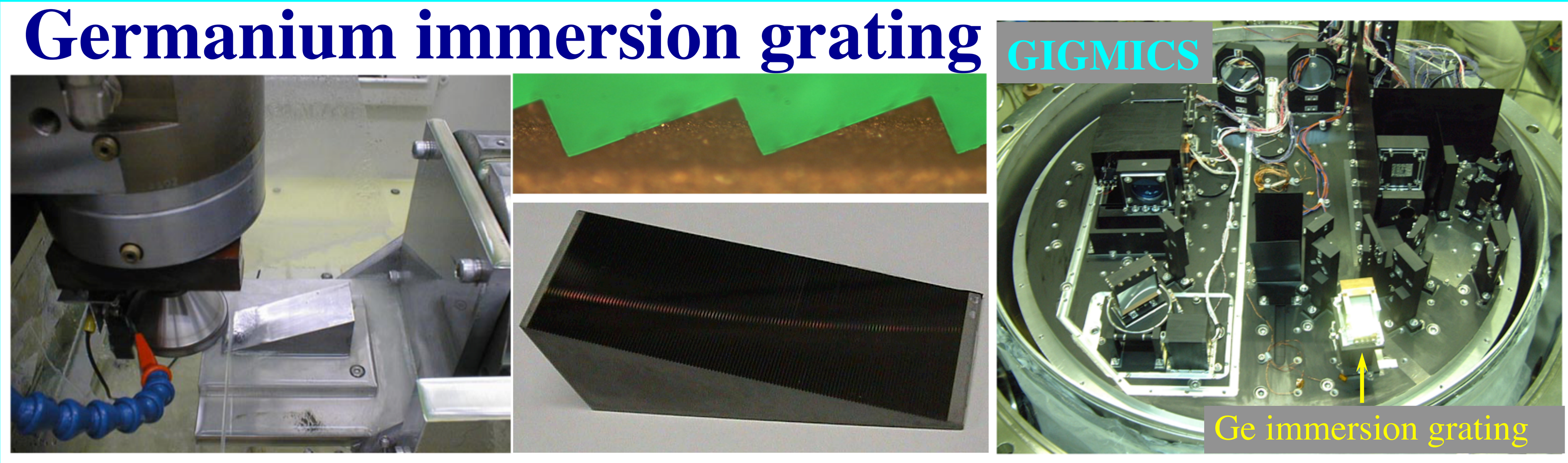
Quasi-Bragg immersion grating



(Ebizuka, SPIE 6273, 2006)

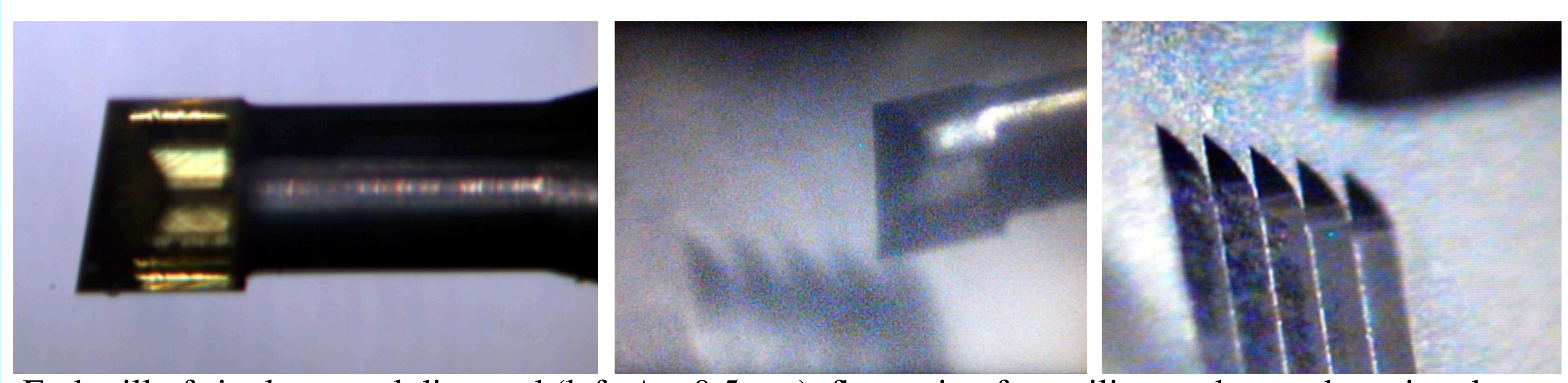
Schematic representation of quasi-Bragg immersion (QBI) grating.

Germanium immersion grating

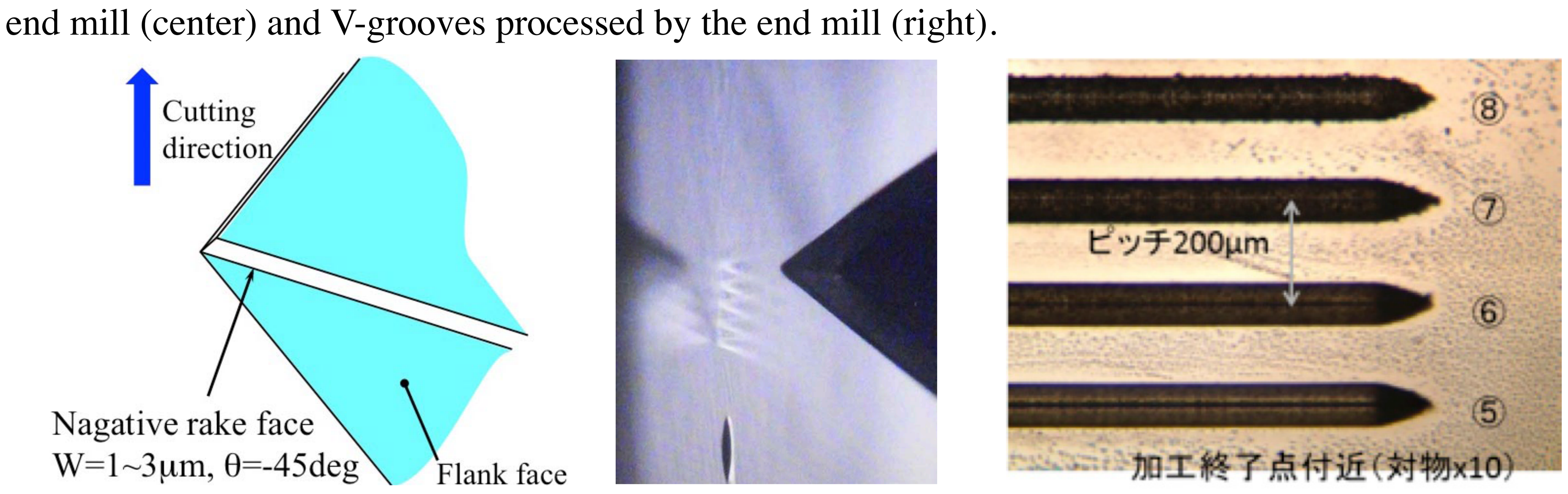


Fabrication of a germanium immersion grating with size of 30 by 30 by 72 spent ~ 400 hours by means of a nano-precision machine tool and ELID grinding method. (Ebizuka, SPIE 4842, 2003)

Test fabrication of V-grooves on silicon and germanium



End mill of single-crystal diamond (left, ϕ = 0.5mm), fly-cutting for a silicon substrate by using the end mill (center) and V-grooves processed by the end mill (right).



V-bit with negative rake angle (left). Setting of a V-bit and silicon wafer to nano-precision machine tool (center). End points of V-grooves on silicon wafer processed by shave cutting of V-bit (right).

Conclusions

- VPH grating achieves high angular dispersion and high efficiency for the 1st diffraction order, as well as versatile for moderate angular dispersion.
- Volume binary grating and birefringence Bragg binary (3B) grating achieve high diffraction efficiency up to 100% for non-polarized light of the 1st diffraction order and of higher diffraction orders (utilized for echelle spectrograph).
- Test fabrication of volume binary grating and 3B grating are performed by Toyoda Technological Institute and by CITIZN Holdings, respectively.
- Quasi-Bragg (QB) grating and quasi-Bragg immersion (QBI) grating, which mirror plates laminated by pressure fusion of gold films, are feasible even for echelle spectroscopy of visible wavelength.
- Silicon and germanium immersion gratings with step-like grooves, which processed by the latest diamond cutting tool, are expected to realize ideal performance for near infrared and mid-infrared, respectively.