POLARIZATION MEASUREMENT AND MODELING OF VISIBLE SYNCHROTRON RADIATION AT SPEAR3

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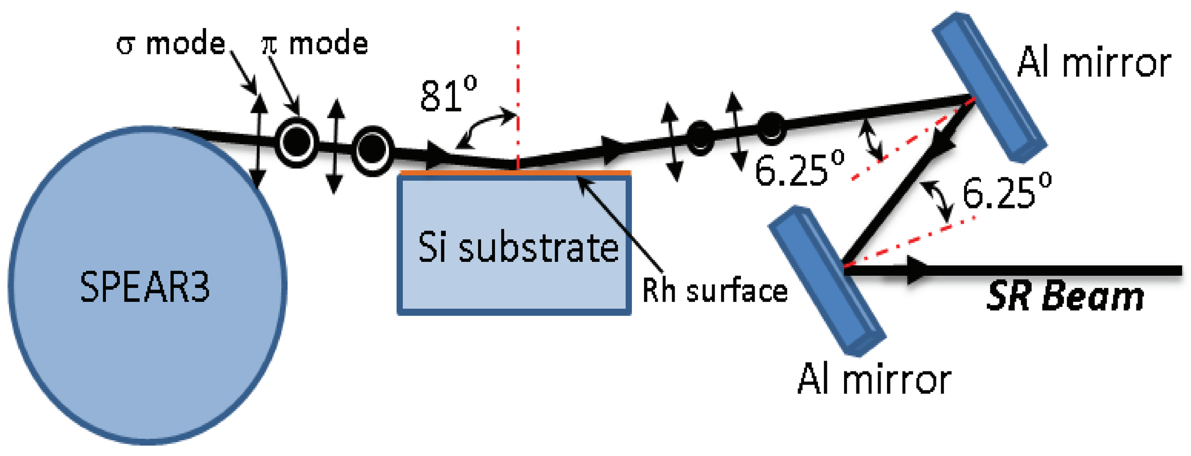
Abstract

- Model the SR beam polarization using Schwinger's equations for the angular spectral power density.
- Use Fresnel's reflection laws at the extraction mirror to model visible light at the optical bench.
- Measure polarization with a polarizer and quarter wave plate to yield Stokes' parameters S_0-S_3
- Plot the beam polarization state on the Poincaré sphere and compare with theory.

The SPEAR3 Diagnostic beamline

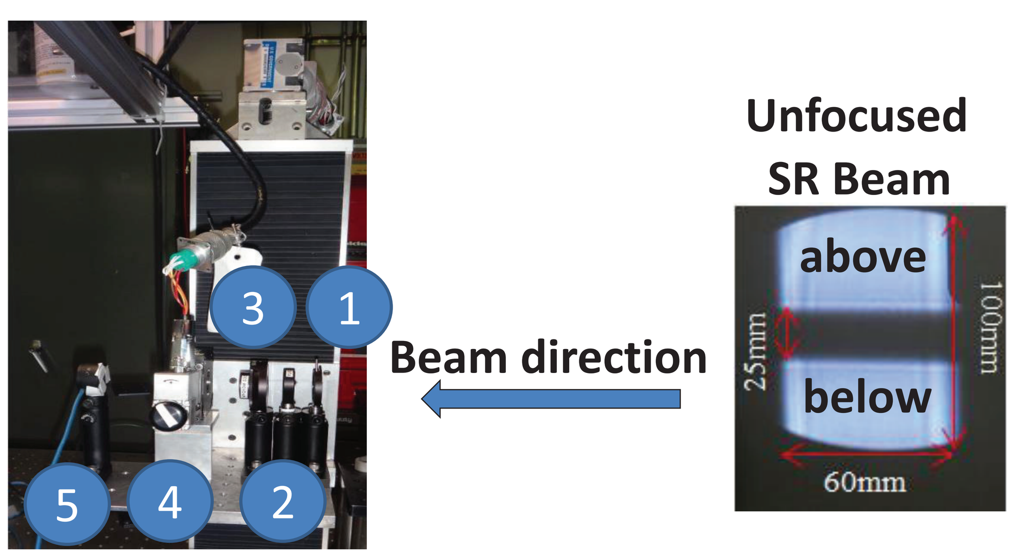


Schematic for SR beam extraction mirror

Properties of the Rh-coated extraction mirror

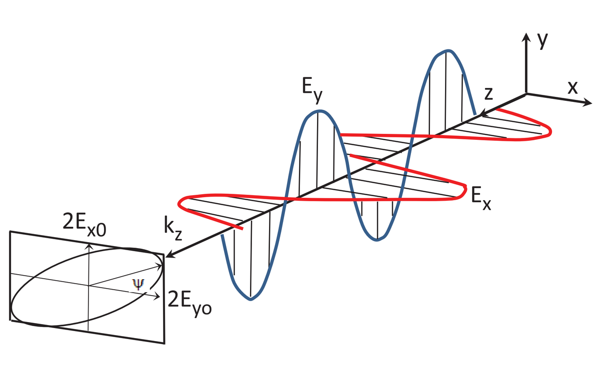
Parameters	Value
Wavelength (nm)	532
Refractive index (n_r)	2.633
Extinction index (k_i)	3.306
Reflection coefficient r_s (π mode)	0.957
Reflection coefficient r_p (σ mode)	0.508
Intensity ratio $I_p/I_s=(r_p/r_s)^2$	0.2818
π mode phase shift $\Delta\phi_S$	-176.726°
σ mode phase shift $\Delta\phi_P$	119.555°
Phase difference $\Delta\phi_{S-P}$	Above=153° Below=333°

Continuous –Scan Measurement system.

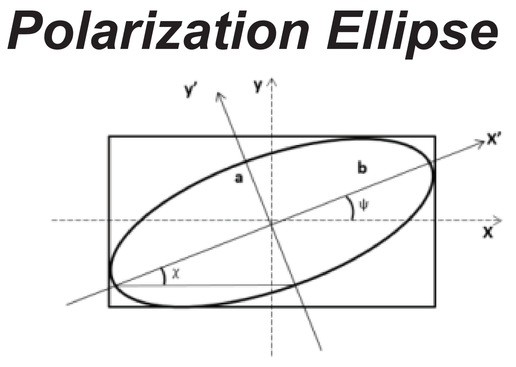


1:iris, 2:BP filter, 3:quarter wave plate, 4: beam polarizer, 5: DC power meter.

Elliptical Polarization

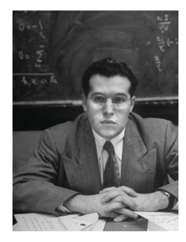


Polarization Ellipse

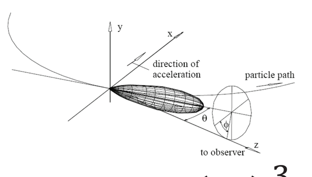


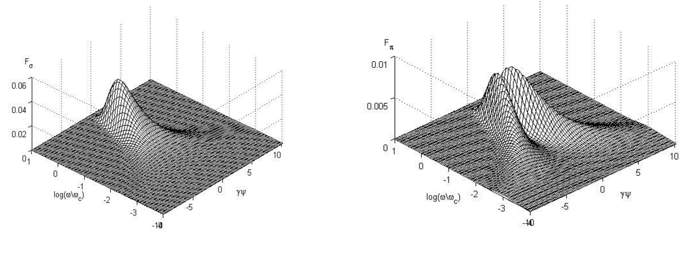
$$\frac{E_x^2}{E_{x0}^2} - 2\frac{E_xE_y}{E_{x0}E_{y0}}\cos\delta + \frac{E_y^2}{E_{y0}^2} = sin^2\delta$$

Schwinger's Equations



Julian Schwinger





Horizontal Polarization Vertical Polarization

$$F_\sigma = \left(\frac{3}{2\pi}\right)^3 \left(\frac{\omega}{2\omega_c}\right)^2 (1+\gamma^2\psi^2)^2 K_{\frac{2}{3}}^2\left(\frac{\omega}{2\omega_c}(1+\gamma^2\psi^2)^{\frac{3}{2}}\right)$$

$$F_\pi = \left(\frac{3}{2\pi}\right)^3 \left(\frac{\omega}{2\omega_c}\right)^2 \gamma^2\psi^2(1+\gamma^2\psi^2)^2 K_{\frac{1}{3}}^2\left(\frac{\omega}{2\omega_c}(1+\gamma^2\psi^2)^{\frac{3}{2}}\right)$$

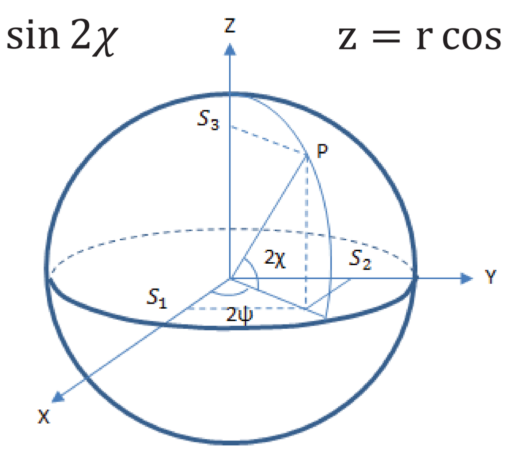
Stokes' Equations

$$S_0 = E_{x0}^2 + E_{y0}^2 = I_{0^o} + I_{90^o}$$
$$S_1 = E_{x0}^2 - E_{y0}^2 = I_{0^o} - I_{90^o}$$
$$S_2 = 2E_{x0}E_{y0}\cos(\delta) = I_{45^o} - I_{135^o}$$
$$S_3 = 2E_{x0}E_{y0}\sin(\delta) = I_{45^o}^{QWP} - I_{135^o}^{QWP}$$

G.G. Stokes

The Poincaré Sphere

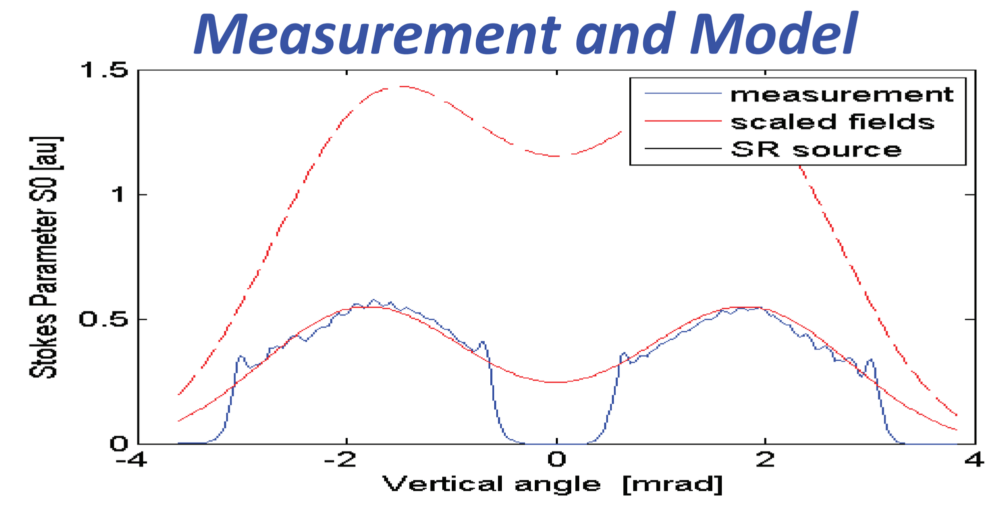
$$S_1 = S_0\cos 2\chi\cos 2\Psi \quad x = r\sin\theta\cos\phi \quad \theta = 90° - 2\chi$$
$$S_2 = S_0\cos 2\chi\sin 2\Psi \quad y = r\sin\theta\sin\phi \quad \phi = 2\psi$$
$$S_3 = S_0\sin 2\chi \quad z = r\cos\theta$$

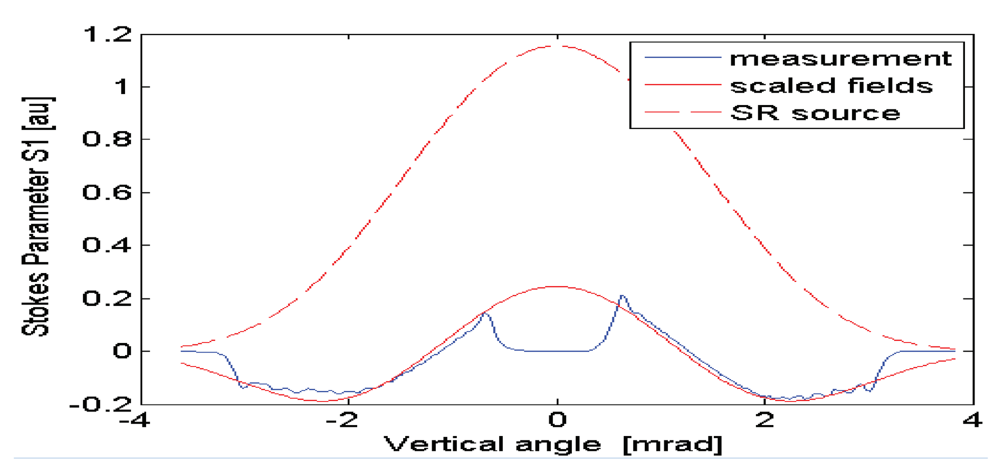


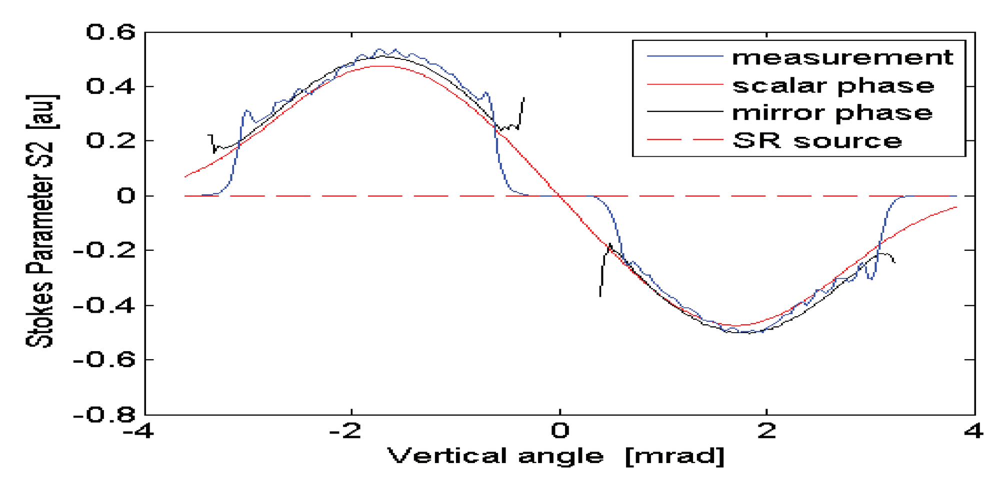
Henri Poincaré

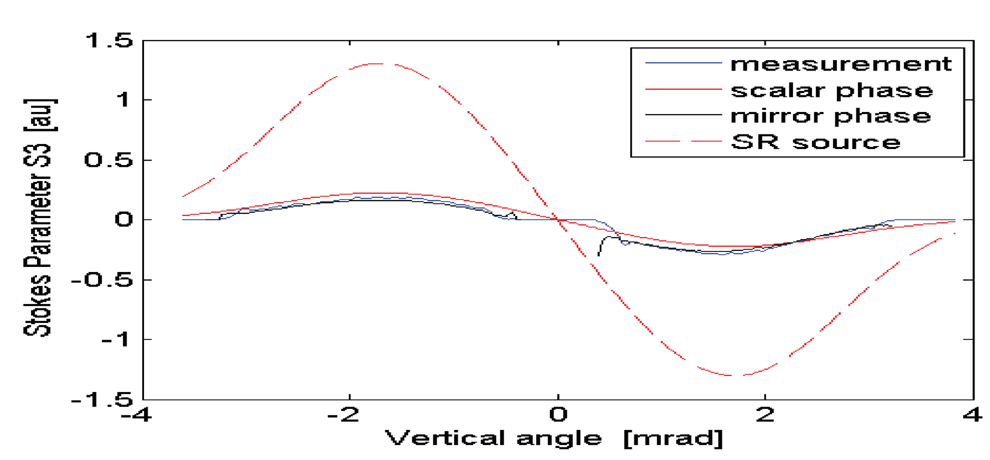
$$\tan 2\Psi = \frac{2E_{ox}E_{oy}\cos\delta}{E_{ox}^2 - E_{oy}^2} = \frac{S_2}{S_1} \qquad \sin 2\chi = \frac{2E_{ox}E_{oy}\sin\delta}{E_{ox}^2 + E_{oy}^2} = \frac{S_3}{S_0}$$

Stokes Parameters: Measurement and Model

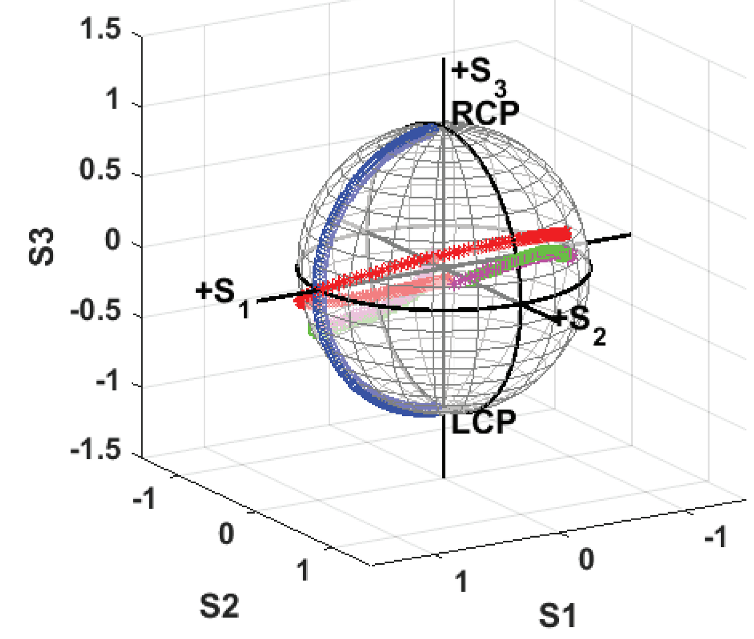


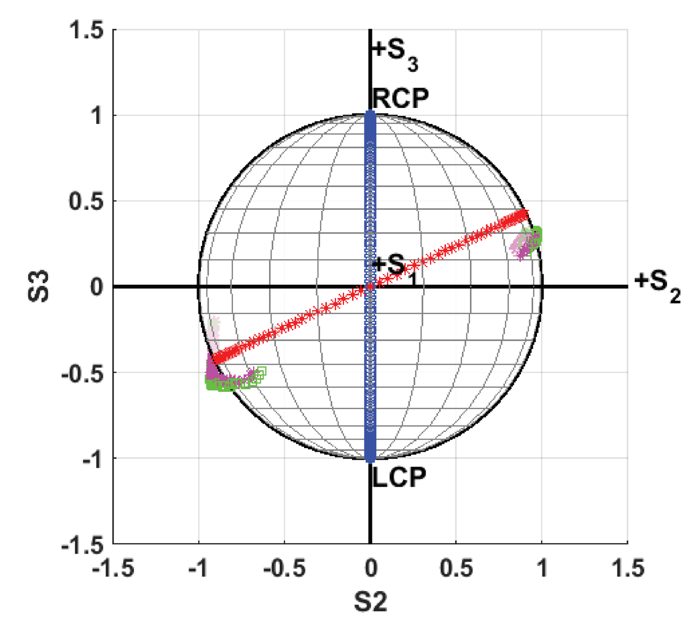


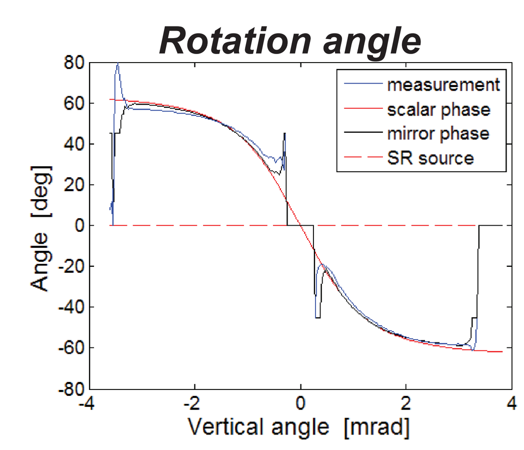


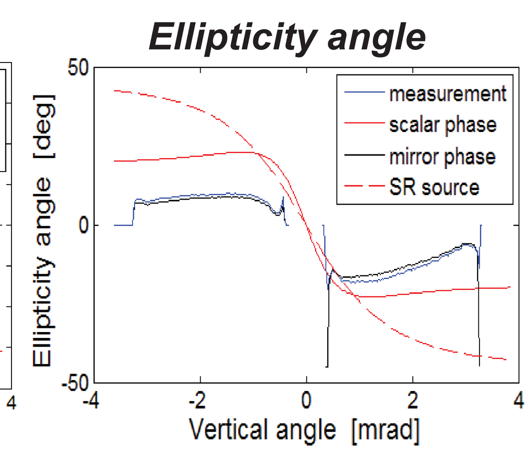


Poincaré Sphere: Measurement and Model

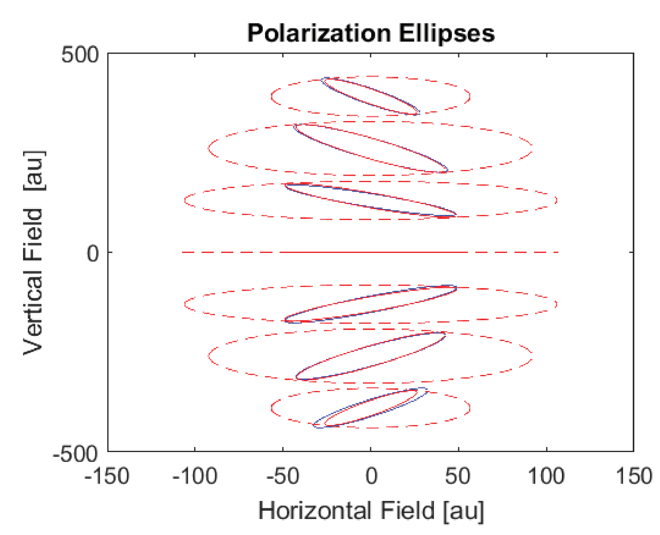








Polarization ellipse rotation and ellipticity as a function of vertical scan profile



SR beam polarization ellipse evaluated at different vertical elevation angles

Summary

- Polarization measurements for the unfocused visible SR beam in SPEAR3
- Vertical profile modeled with Schwinger's equations
- Stokes' parameters represent the beam polarization state.
- Thin-film Rh-coated extraction mirror has a significant influence on field polarization
- Poincaré sphere representation of the variation in beam polarization with vertical observation angle

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