Goos-Hänchen shift

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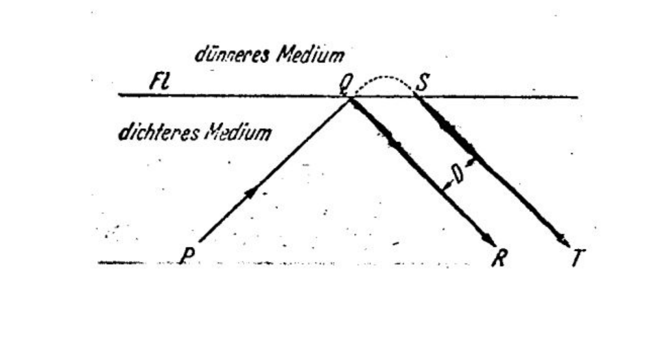
Summary

01 Introduction

The discovery

1730: Newton

1947: Fritz Goos and Hilda Hänchen



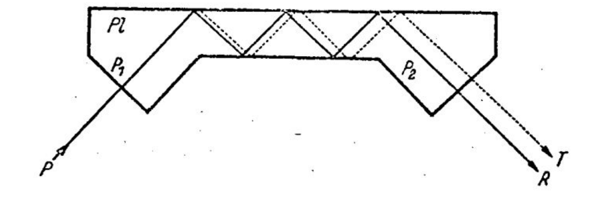


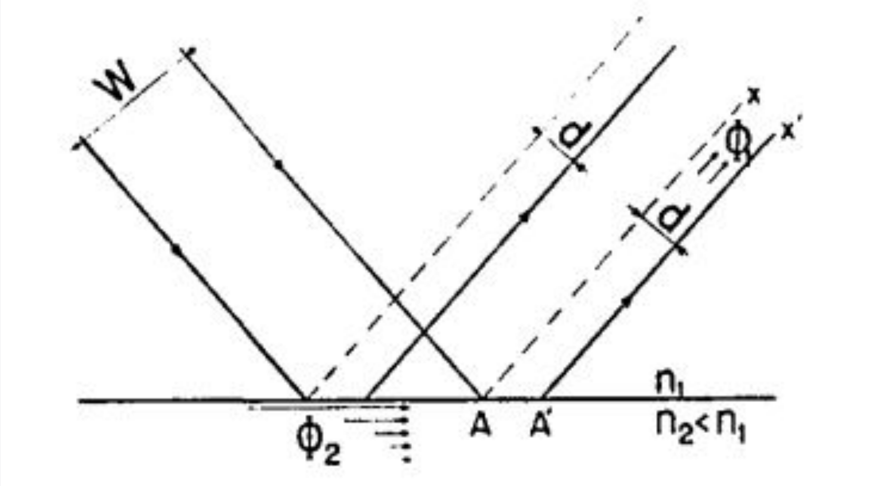
Fig. 4 : Principle of multiple reflection

And what came next...

- 1948: Artmann and von Fragstein
- 1960: Brekhoviskihk
- 1964: Renard
- 1970: Lotsch
- 1972: Chiu and Quinn
- 1972: Imbert-Fedorov
- 1977: McGuirk and Carniglia

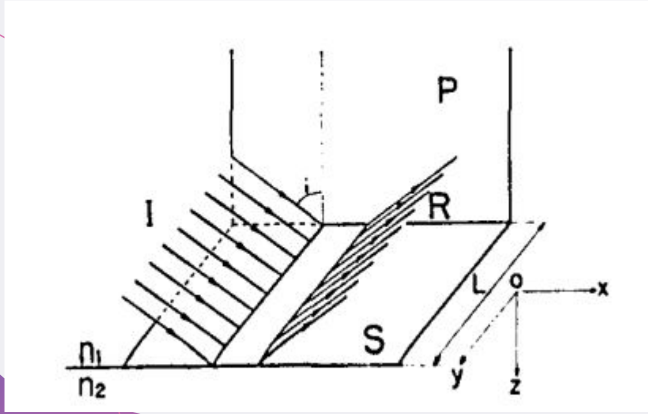
02 Goos-Hänchen shift for a plane surface

Goos-Hänchen shift for a plane surface



Case A: Electric vector perpendicular to the plane of incidence (TE)

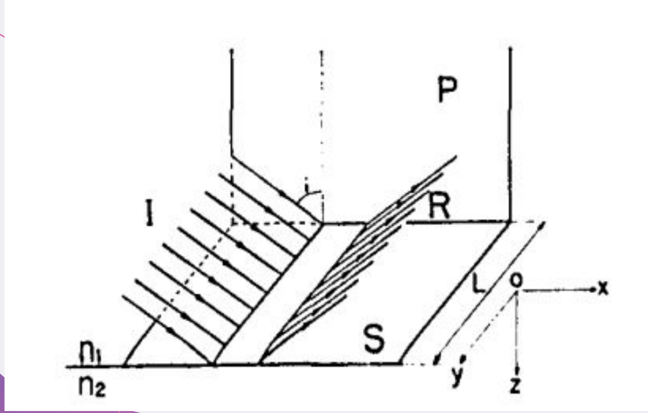
$$M_2^2 = \frac{64\pi^2 D_1^2}{K_1\mu_1} \cdot \frac{\cos^2\theta_i\,(2\sin^2\theta_1 - K\mu)}{\mu^2\cos^2\theta_i + \sin^2\theta_i - K\mu}$$



$$M_1 = \frac{4\pi}{\sqrt{K_1\mu_1}} D_1$$

Case A: Electric vector perpendicular to the plane of incidence (TE)

$$\Phi_2 = \frac{L}{32\pi^2}\left(\frac{\mu_2}{K_2}\right)^{1/2}\frac{1-\gamma_2^2}{1+\gamma_2^2}\frac{\lambda_2}{\gamma_2}M_2^2$$



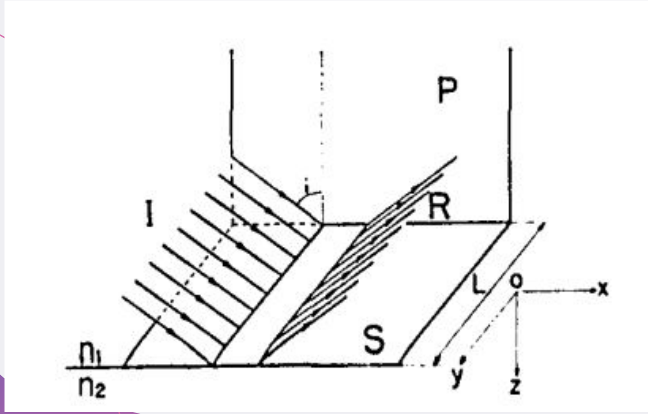
$$\gamma_2^2 = 1 - n^2 / \sin^2\theta_i$$

$$n^2 = n_2^2/n_1^2 = K_2\mu_2/K_1\mu_1 = K\mu$$

$$\lambda_2 = \lambda_{vacuum}/n_2$$

Case A: Electric vector perpendicular to the plane of incidence (TE)

$$\Phi_1 = \frac{L d_{TE}}{8\pi}\left(\frac{\mu_1}{K_1}\right)^{1/2} M_1^2$$



By energy conservation:

$$\Phi_1 = \Phi_2$$

Case A: Electric vector perpendicular to the plane of incidence (TE)

$$d_{TE} = \frac{1}{\pi} \frac{\mu \sin\theta_i \cos^2\theta_i}{\mu^2 \cos^2\theta_i + \sin^2\theta_i - n^2} \frac{\lambda_1}{\sqrt{\sin^2\theta_i - n^2}}$$

Case A: Electric vector perpendicular to the plane of incidence (TE)

$$d_{TE} = \frac{1}{\pi} \frac{\mu \sin\theta_i \cos^2\theta_i}{\mu^2 \cos^2\theta_i + \sin^2\theta_i - n^2} \frac{\lambda_1}{\sqrt{\sin^2\theta_i - n^2}}$$

For $\sin\theta_i \simeq n$

$$d_{TE} \simeq \frac{\sin\theta_i}{\pi} \frac{\lambda_1}{\sqrt{\sin^2\theta_i - n^2}}$$

Artmann and von Fragstein's equation

Case B: Electric vector parallel to the plane of incidence (TM)

$$d_{TM} = \frac{1}{\pi} \frac{K \sin \theta_i \cos^2 \theta_i}{K^2 \cos^2 \theta_i + \sin^2 \theta_i - n^2} \frac{\lambda_1}{\sqrt{\sin^2 \theta_i - n^2}}$$

Case B: Electric vector parallel to the plane of incidence (TM)

$$d_{TM} = \frac{1}{\pi} \frac{K \sin\theta_i \cos^2\theta_i}{K^2 \cos^2\theta_i + \sin^2\theta_i - n^2} \frac{\lambda_1}{\sqrt{\sin^2\theta_i - n^2}}$$

For $\sin\theta_i \simeq n$

$$d_{TM} \simeq \frac{\sin\theta_i}{\pi n^2} \frac{\lambda_1}{\sqrt{\sin^2\theta_i - n^2}}$$

Artmann and von Fragstein's equation

Renard's arguments

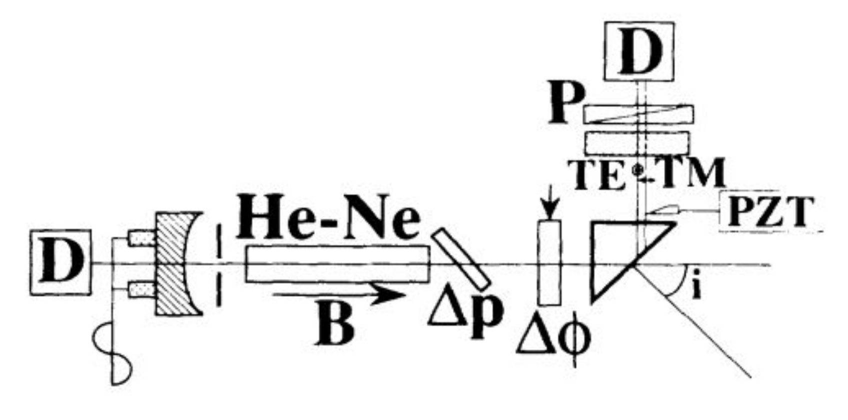
Artmann and von Fragstein's equation

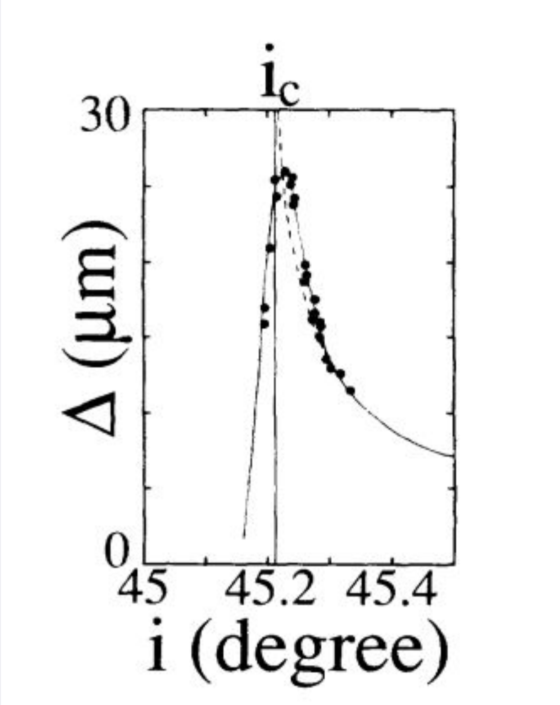
$$d_{TE} \simeq \frac{\sin\theta_i}{\pi}\frac{\lambda_1}{\sqrt{\sin^2\theta_i - n^2}}$$

$$d_{TM} \simeq \frac{\sin\theta_i}{\pi n^2}\frac{\lambda_1}{\sqrt{\sin^2\theta_i - n^2}}$$

03 Measuring the Goos-Hänchen shift

The Bretenaker method (1992)





There are so many ways....

1950: Goos and Hänchen/Wolter method

1972: Imbert-Fedorov

1977: Cowan and Anicin method

2008: Schwefel

04 Conclusion

Nowadays....

- Nanophotonics and metasurfaces
- Sensitive detection of biological molecules
- Giant Goos-Hänchen shift

Thank you!