

Heterodyne Interferometry and Optical Nonlinearity

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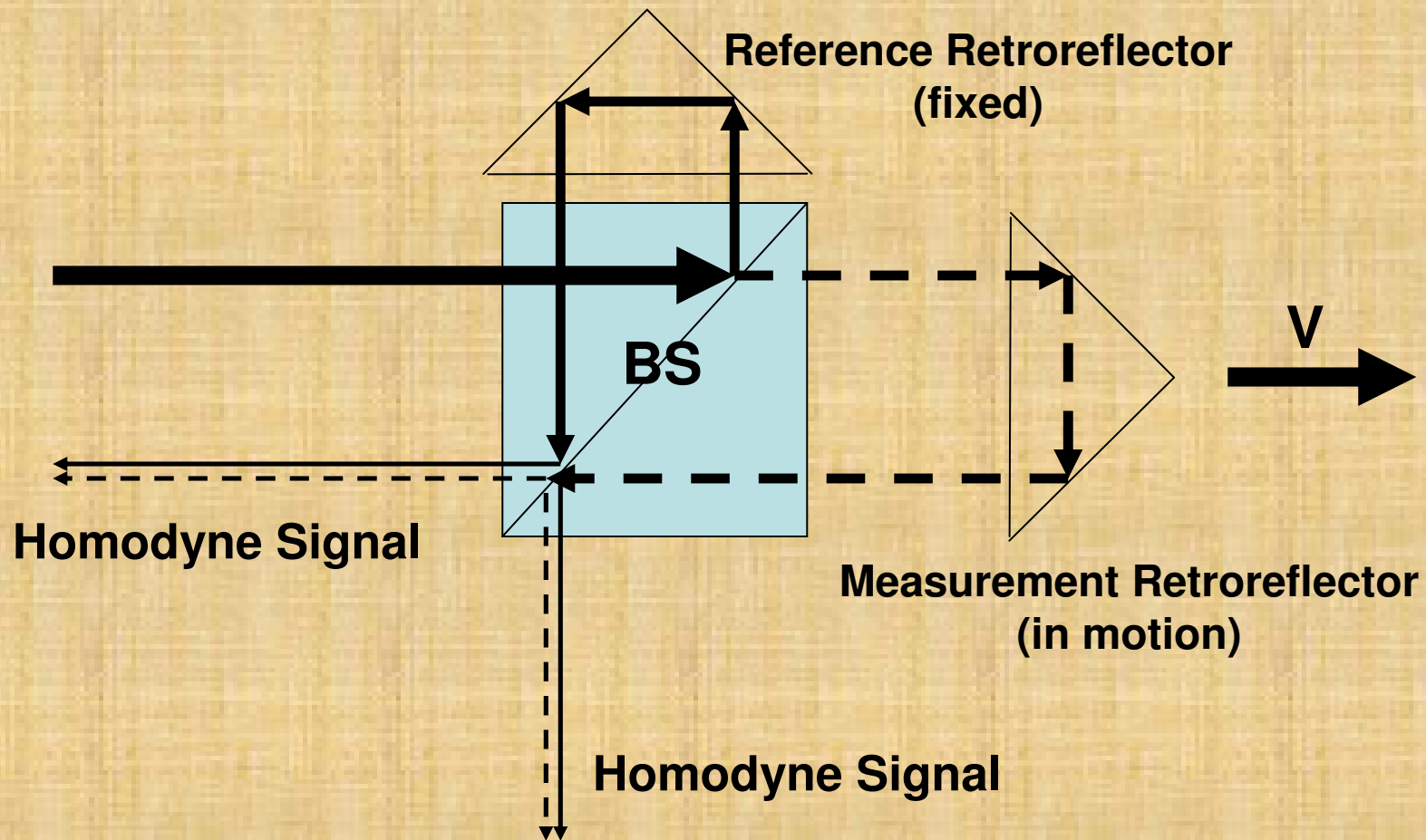
OPTI696BX

December 6, 2006

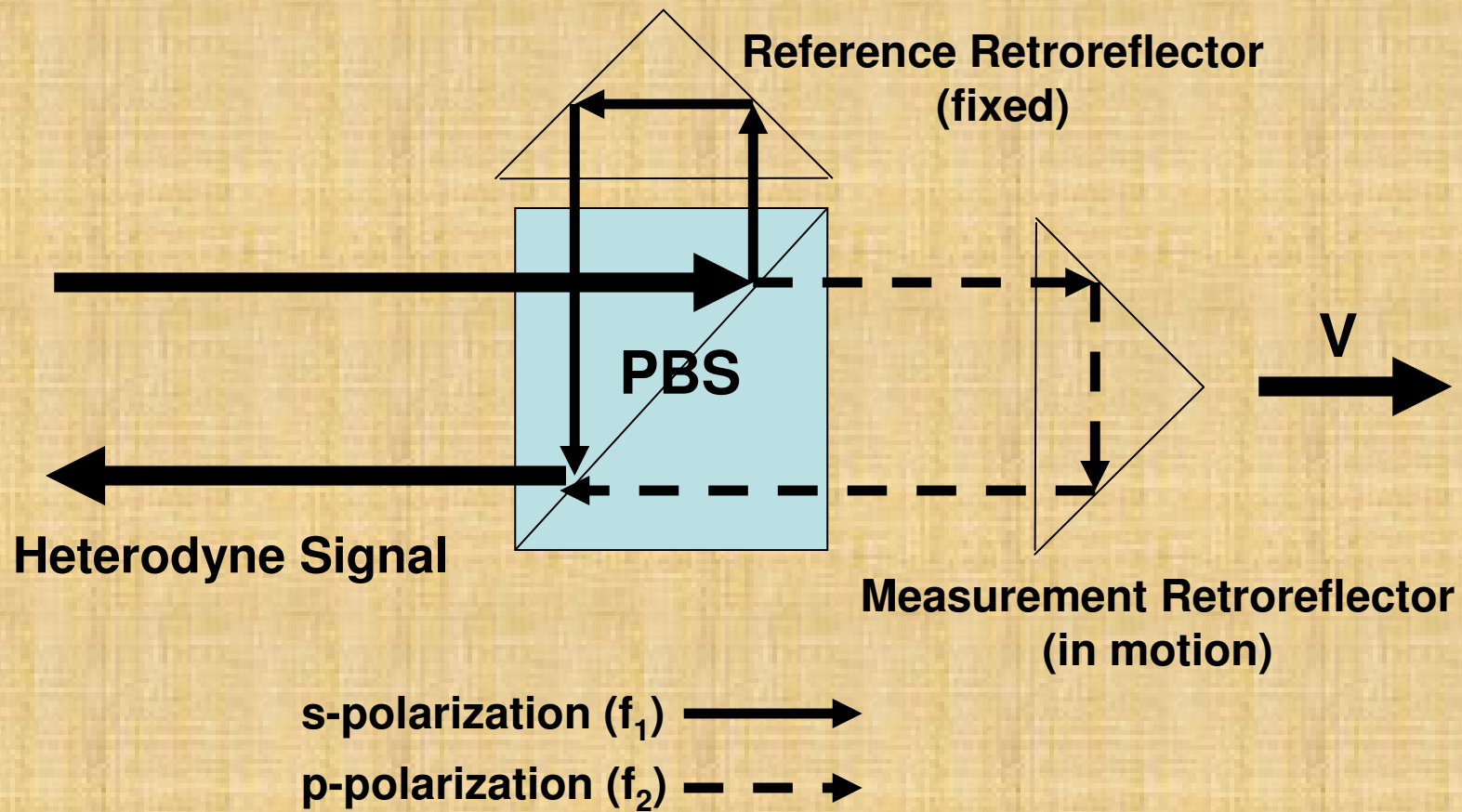
Outline

- I. Heterodyne vs. Homodyne
- II. Cyclic Errors in heterodyne interferometer
- III. Cyclic error compensation

Michelson vs. Heterodyne Michelson



Classic Michelson



Heterodyne Michelson

Interferometer Signals

$$E_1 = A_1 \exp(i2\pi f t + \varphi_1)$$

$$E_2 = A_2 \exp(i2\pi f t + \varphi_2)$$

$$|E|^2 = A_1^2 + A_2^2 + 2A_1A_2 \cos(\Delta\varphi) \quad \text{Classic Michelson Signal}$$

$$E_1 = A_1 \exp(i2\pi f_1 t + \varphi_1)$$

$$E_2 = A_2 \exp(i2\pi f_2 t + \varphi_2)$$

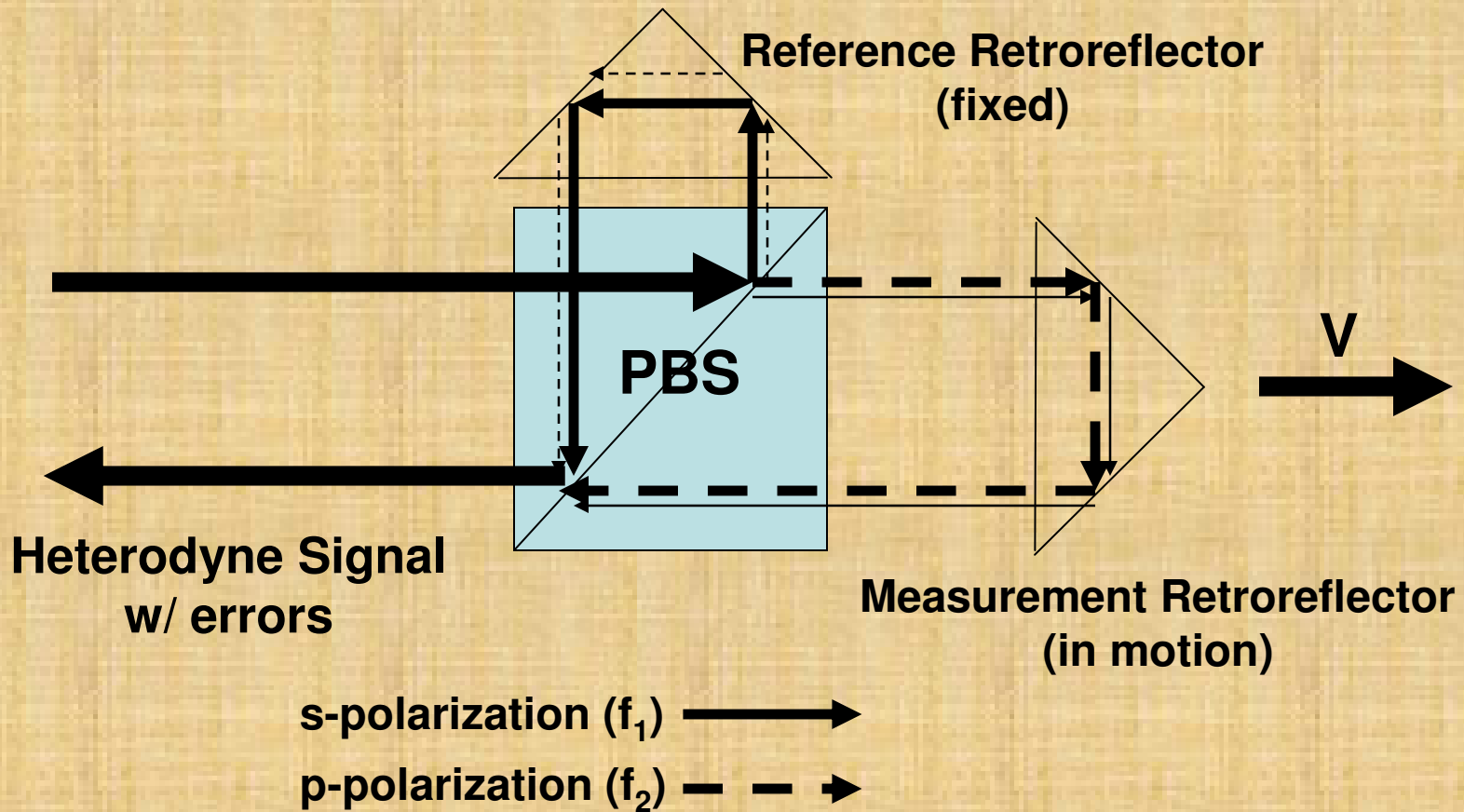
$$|E|^2 = A_1^2 + A_2^2 + 2A_1A_2 \cos(2\pi\Delta f t + \Delta\varphi) \quad \text{Heterodyne Signal}$$

When is heterodyne better?

Heterodyne detection is the way to go if for detecting displacements less than the wavelength of light.

$$\frac{d(\Delta\varphi)}{dt} \ll \Delta f$$

Error Sources



Heterodyne Michelson (w/ errors)

Error Sources

- Non-orthogonal polarizations out of laser head.
- Differential extinction coefficients for the reference and measurement beams at polarizing beam splitter.

$$E_1 = A_1 \exp i(2\pi f_1 t + \varphi_1) + \varepsilon_1 \exp i(2\pi f_2 t + \alpha_1)$$

$$E_2 = A_2 \exp i(2\pi f_2 t + \varphi_2) + \varepsilon_2 \exp i(2\pi f_1 t + \alpha_2)$$

$$|E|^2 = |A_1|^2 + |A_2|^2 + |\varepsilon_1|^2 + |\varepsilon_2|^2$$

DC

$$+ A_1 A_2 \cos(2\pi \Delta f + \Delta \varphi)$$

Heterodyne Signal

$$+ 2A_1 \varepsilon_2 \cos(\varphi_1 - \alpha_2) + 2A_2 \varepsilon_1 \cos(\varphi_2 - \alpha_1)$$

Homodyne Error

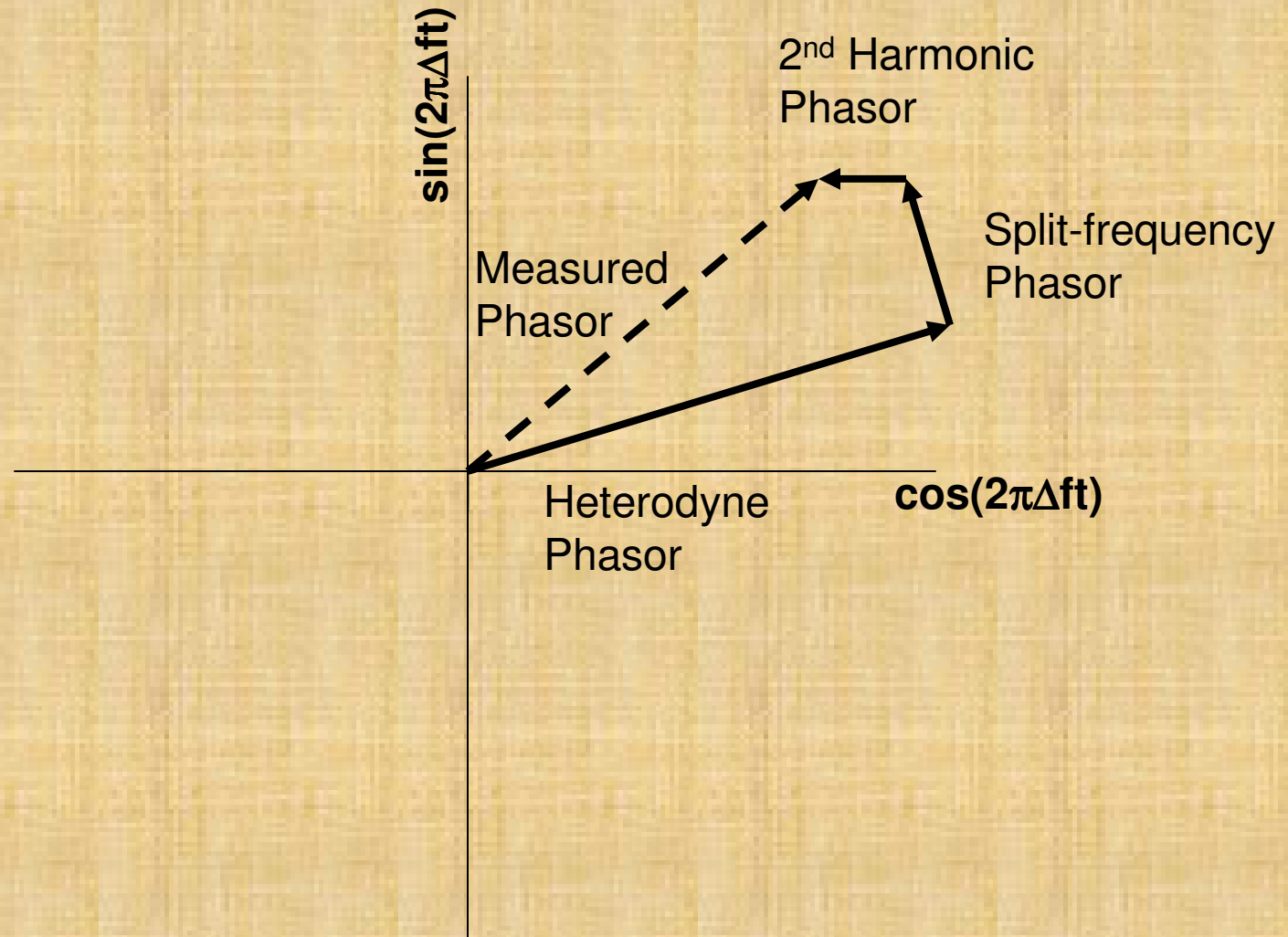
$$+ 2A_1 \varepsilon_1 \cos(2\pi \Delta f + \alpha_1 - \varphi_1) + 2A_2 \varepsilon_2 \cos(2\pi \Delta f + \alpha_2 - \varphi_2)$$

Split-frequency Error

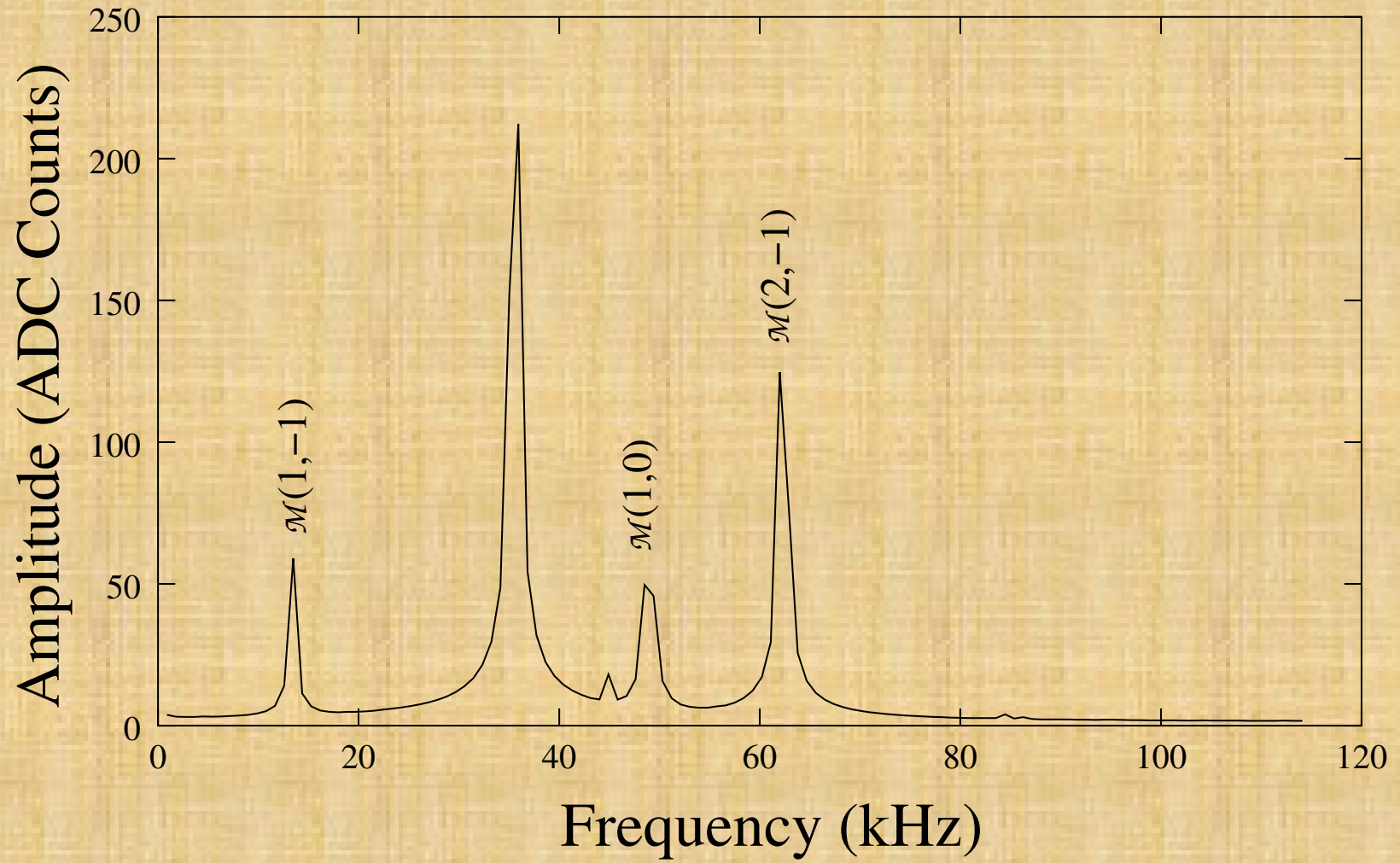
$$+ 2\varepsilon_1 \varepsilon_2 \cos(2\pi \Delta f - \Delta \alpha)$$

2nd Harmonic Error

Phasor Diagram



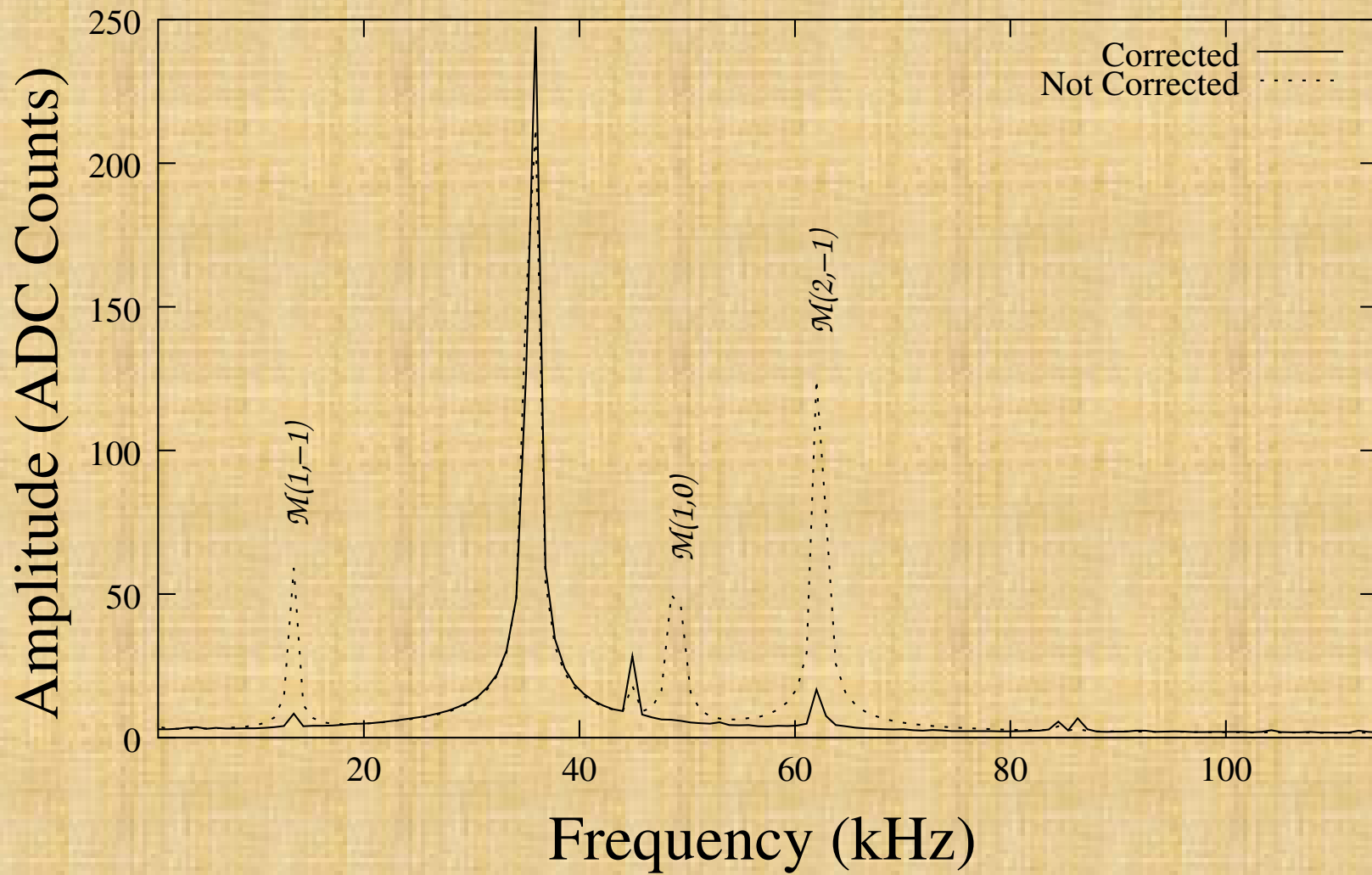
Signal Power Spectrum



Error Compensation

- Adjust alignment and use better quality optics
- Better interferometer design (eliminate differential path errors)
- Signal processing:
 - a.) Frequency domain
 - b.) Digital error correction

Power Spectrum of Corrected Signal



References

- Rosenbluth, A.E. Bobroff, N., Prec. Eng. 1990;12(1):7-11
- Badami, V.G. Patterson S.R., Prec. Eng. 2000;24:41-49