
Nanometer Scale Patterning and Processing

Spring 2016

Lecture 9

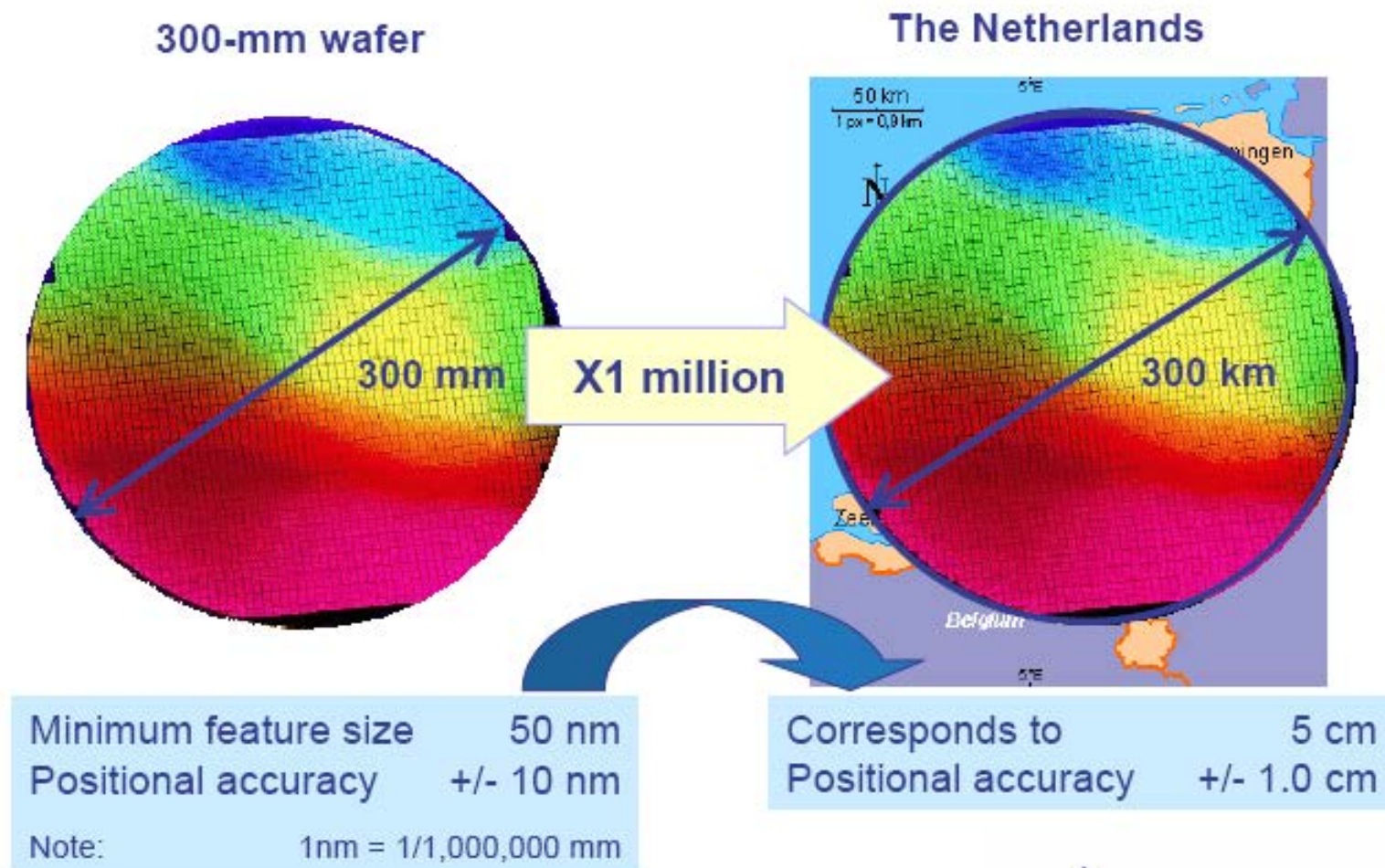
Optical Lithography - Position Detection

Stage Motion Requirements in Projection Lithography Systems

- 300 mm wafer exposed in < 1 minute
- Exposed field: $200\text{ }\mu\text{m} \times 1\text{ mm}$
 - Stage needs to move ~ 240 times (120 times back and forth) to expose a 300 mm wafer
 - Very fast acceleration and deceleration
 - During the scanning, stage speed is constant to maintain identical exposure dose
 - top scanning speed around 0.5 m/s
- Maintain accuracy:
 - 14 nm resolution
 - < 5 nm alignment accuracy.

High Speed and Accuracy

ASML system deliverables: Enlarge a wafer 1 million times and print the Netherlands in 30 seconds



Synchronized Stage Motion

ASML system deliverables

Reticle stage



Wafer stages

Two TWINSKAN™ scanner stages operate at a speed of 550 mm/s with an accuracy of 2 nanometer,

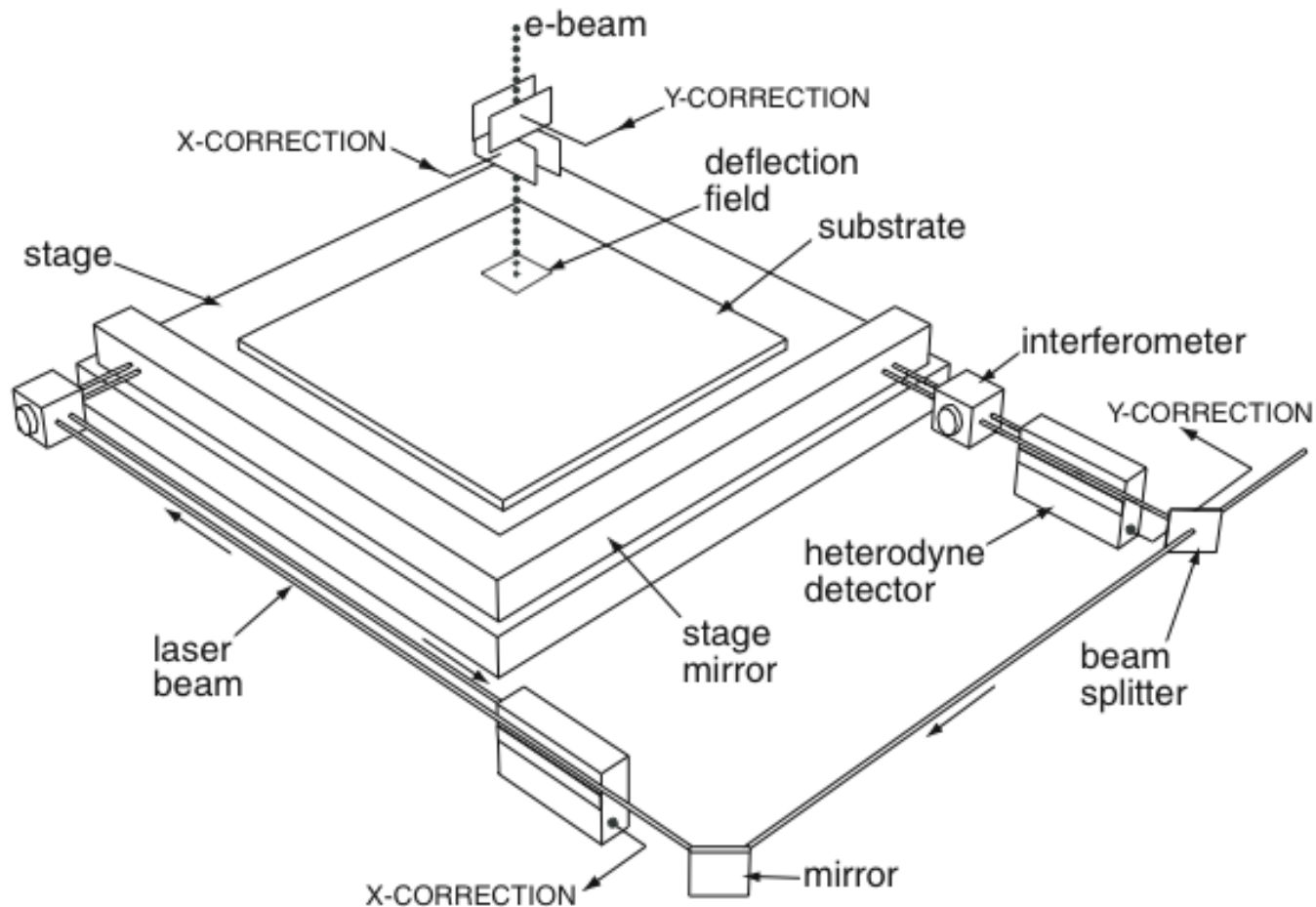


which compares to two 747 jumbo jets flying at 1000 km/hr the exact same route to an accuracy of 0.001 millimeter



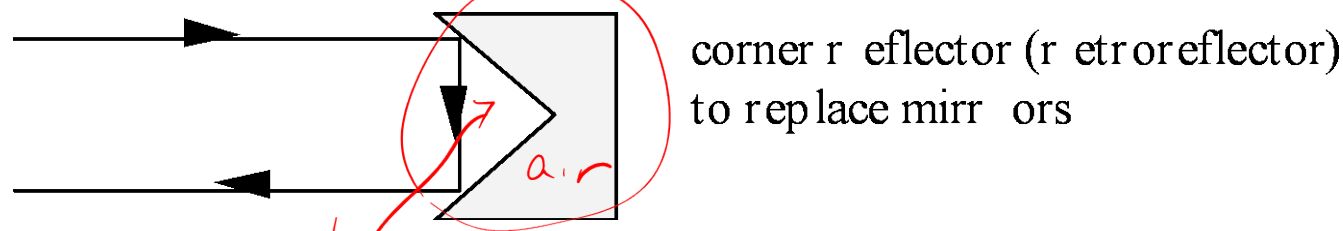
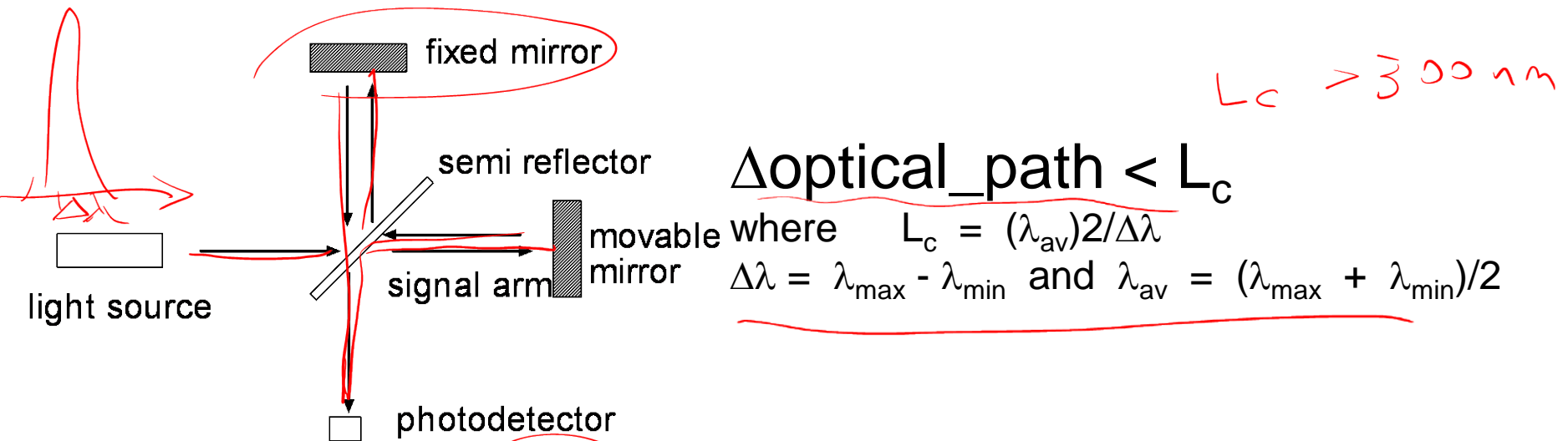
The reticle stage accelerates from 0 to 100 km/hour in 1.6 seconds, leaving every sports car behind.

Laser Interferometer Stage

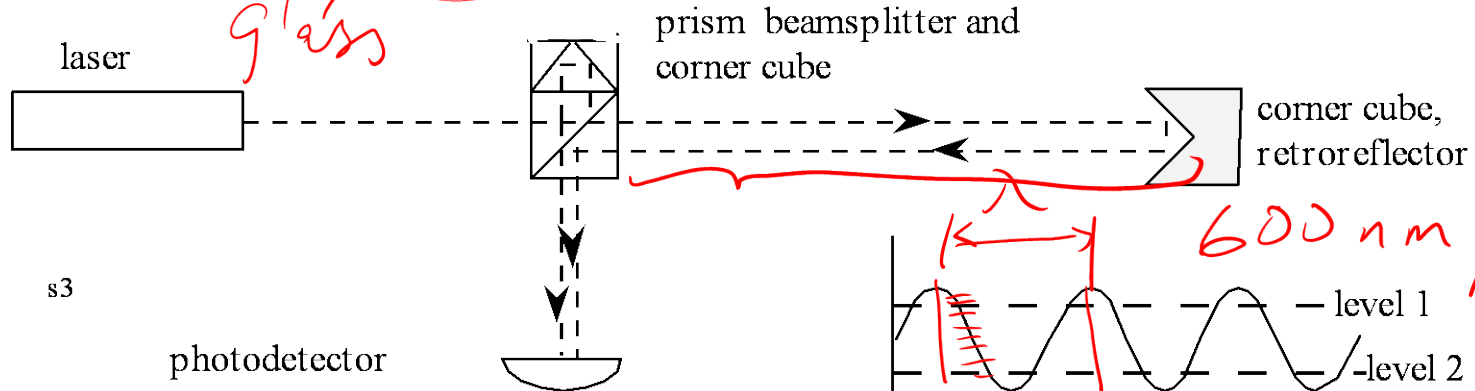


Displacement detection limit: $0.15 \text{ nm } (\lambda/4096)$

Michelson Laser Interferometer

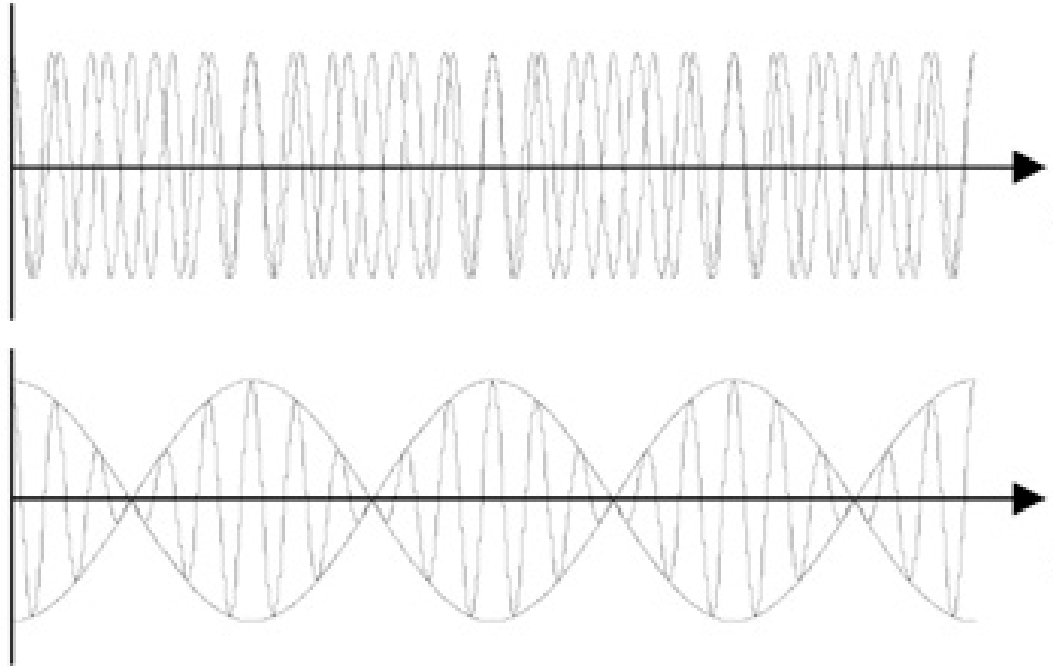


s2



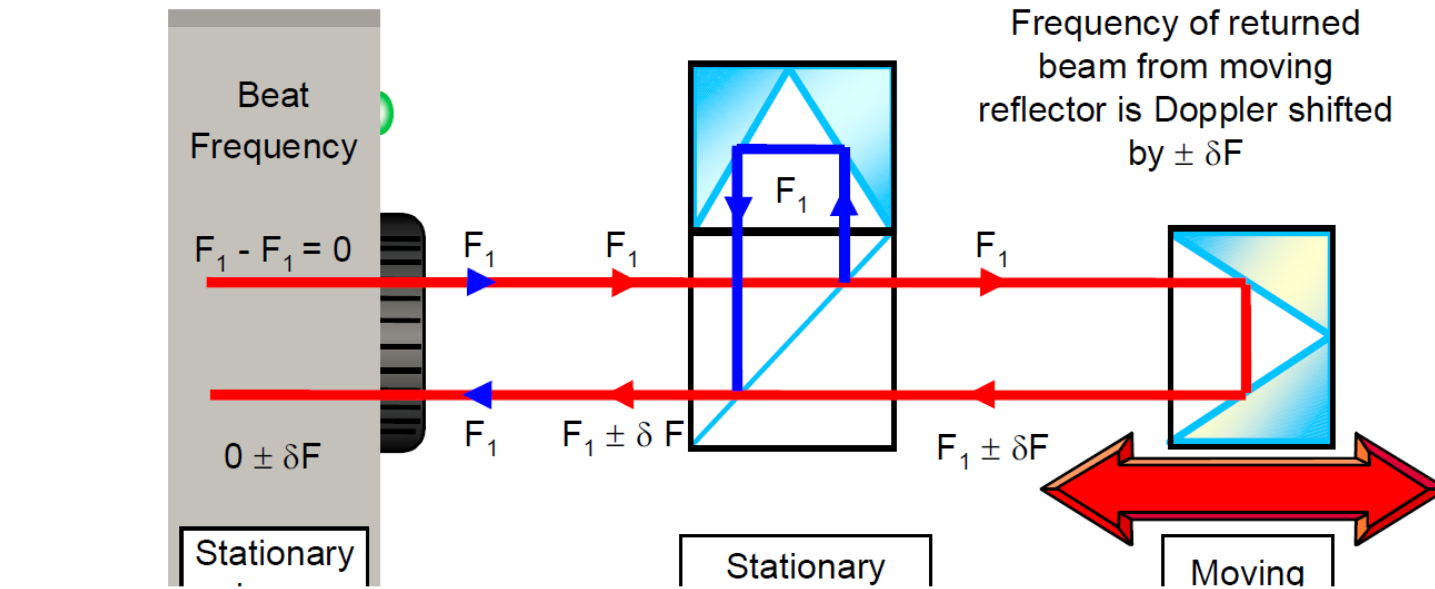
s3

How to Measure Optical Signals



- Direct measurement of oscillating electrical field impossible
- Beating phenomenon between two close frequencies of f_1 and f_2
- Heterodyne detection

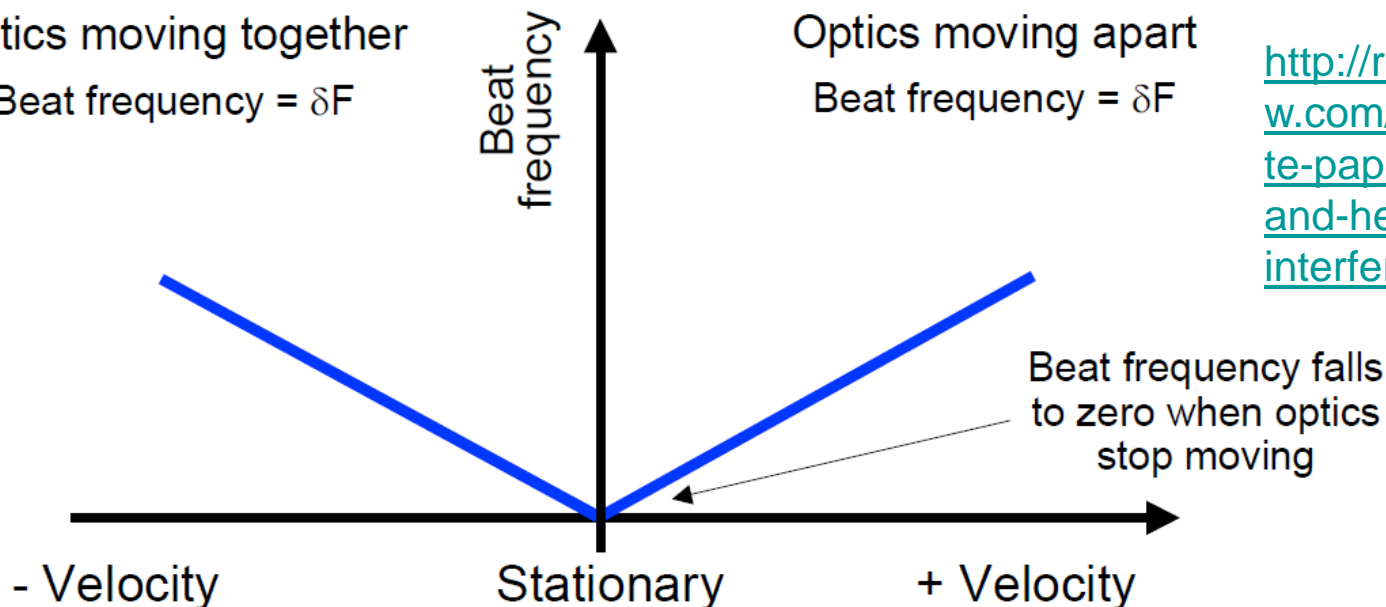
Homodyne Laser Interferometer



Optics moving together
Beat frequency = δF

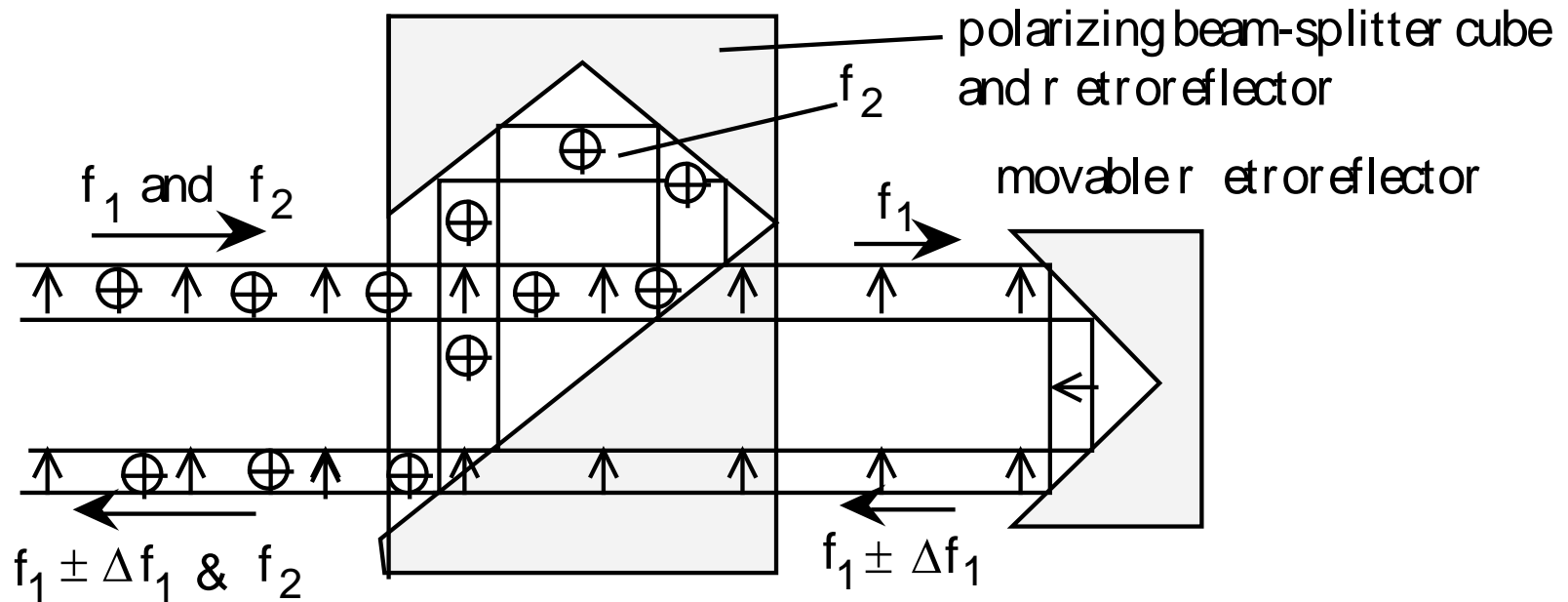
Optics moving apart
Beat frequency = δF

<http://resources.renishaw.com/en/download/white-paper-homodyne-and-heterodyne-interferometry--5653>

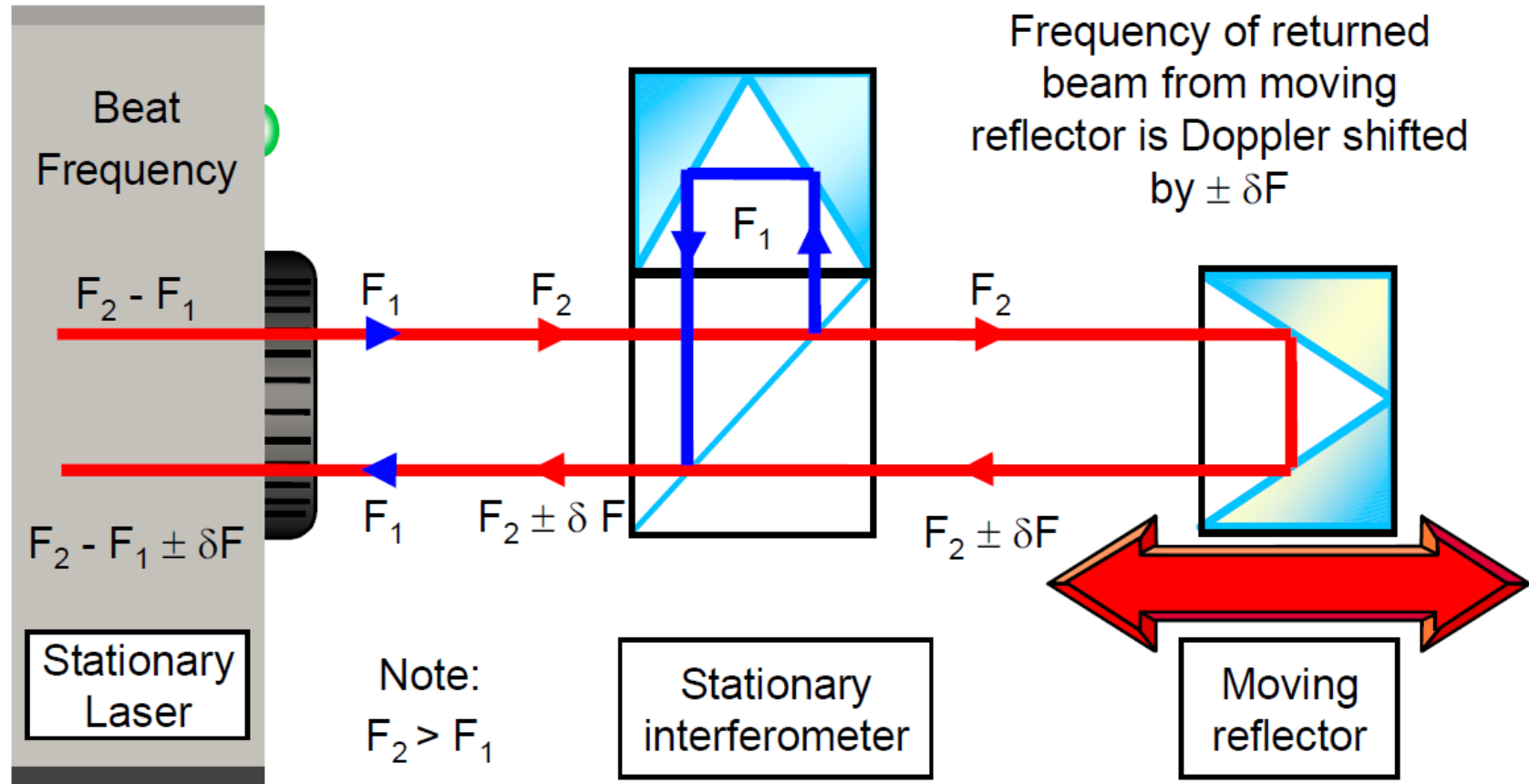


Beam splitter and retroreflector

s5

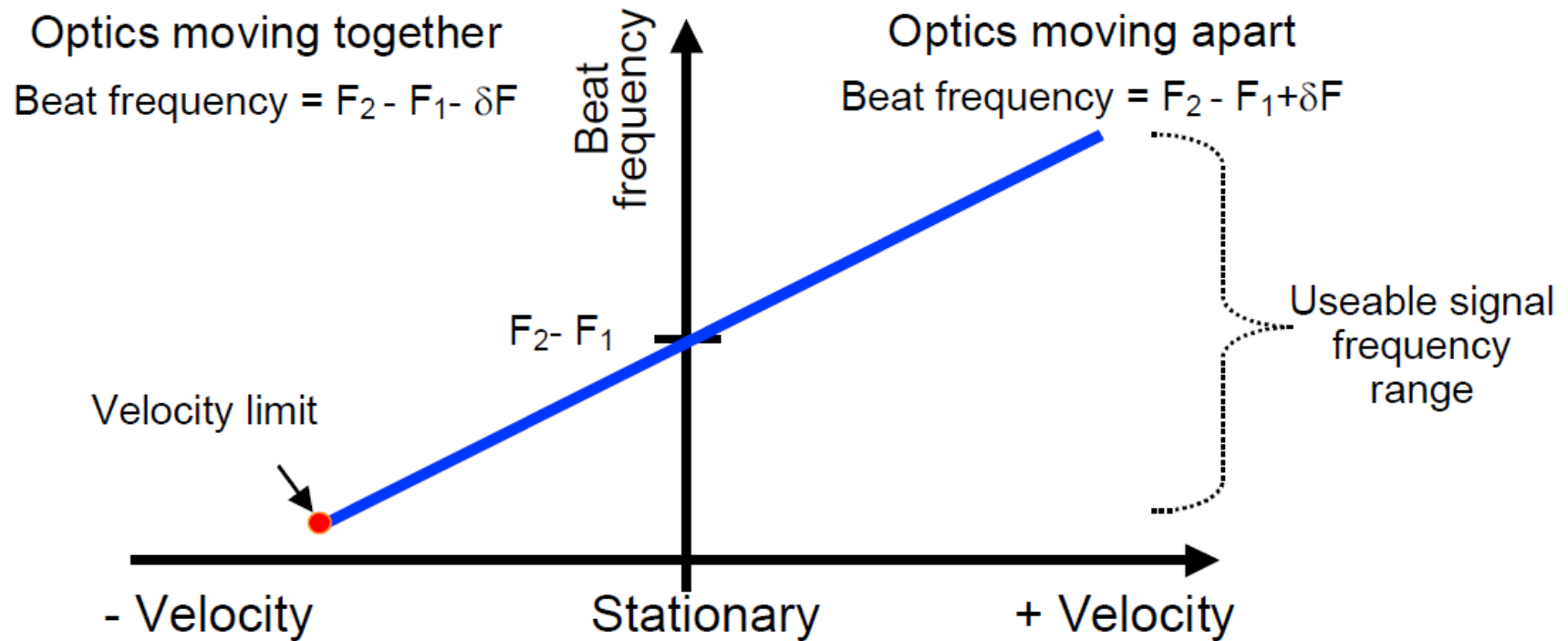


Heterodyne Laser Interferometer



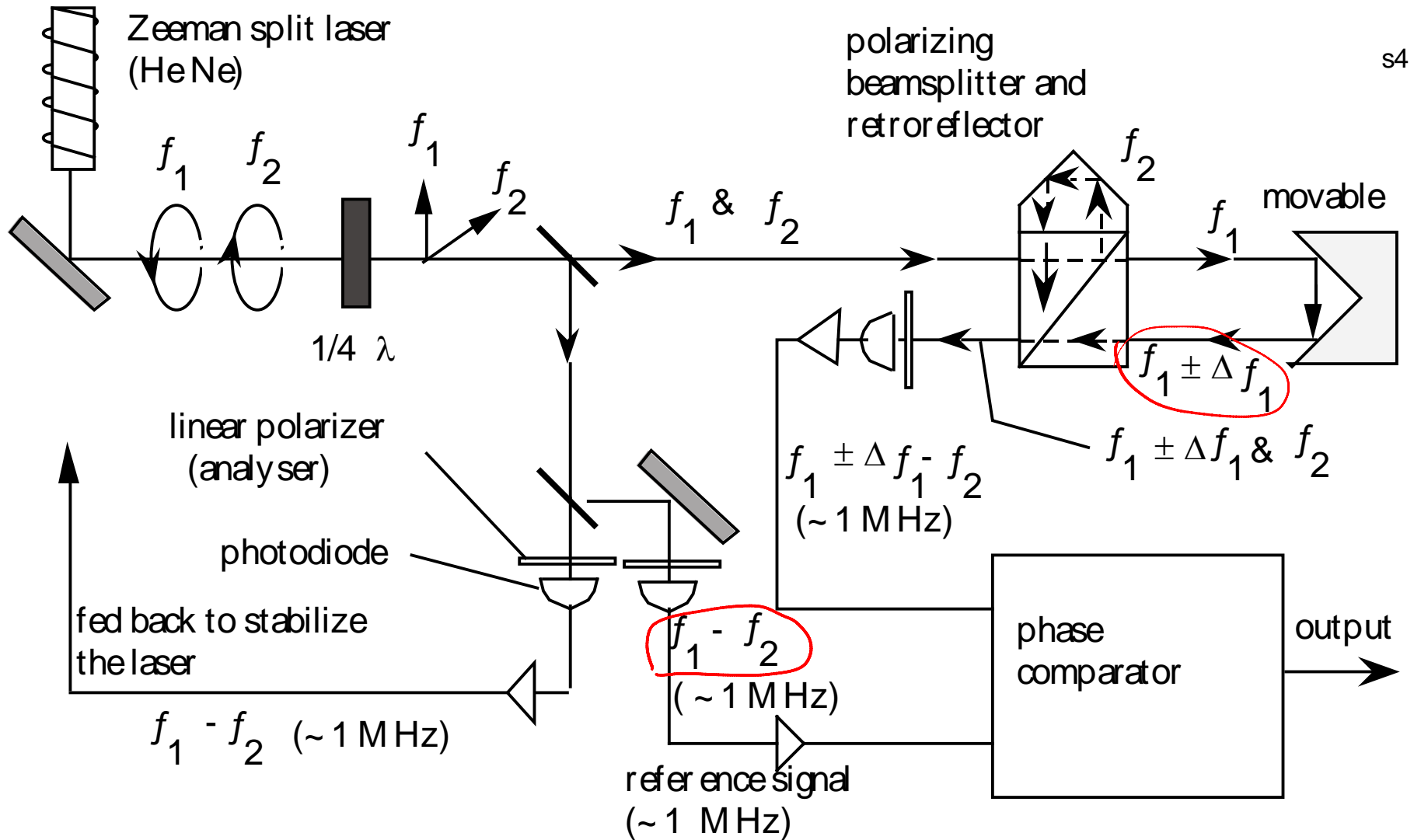
<http://resources.renishaw.com/en/download/white-paper-homodyne-and-heterodyne-interferometry--5653>.

Velocity Measurement with Doppler Effect



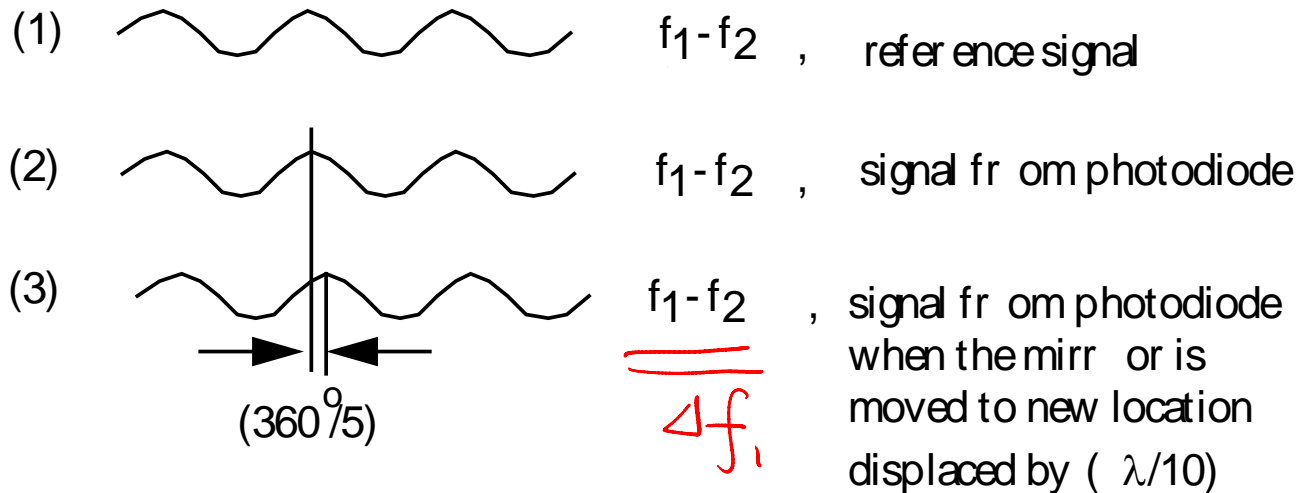
- Measuring the velocity
- Has velocity limit

HP Heterodyne Laser Interferometer



“Phase” interferometer can detect both displacement and velocity

s8



$$\cos(\omega_1 t) + \cos(\omega_2 t) = \cos[(\omega_1 - \omega_2)t] * \cos\left[\frac{(\omega_1 + \omega_2)t}{2}\right]$$

Phase measurement resolution:

$$\lambda/4096 = 0.15 \text{ nm}$$