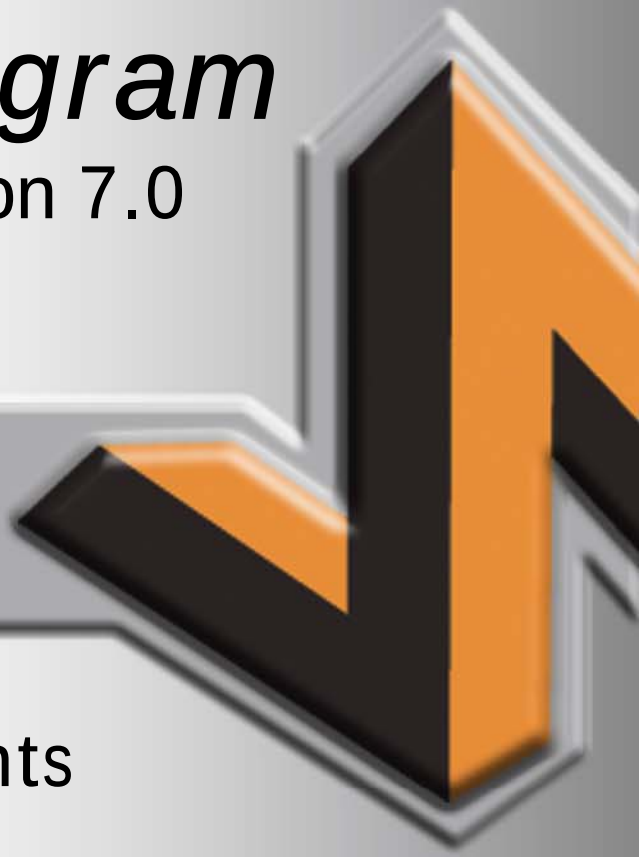
VPI University Program

Photonics Curriculum Version 7.0

Lecture Series



Basic Photonic Measurements

TaM1

Module Prerequisites

- **Introduction to Fiber-Optic Communications I & II**

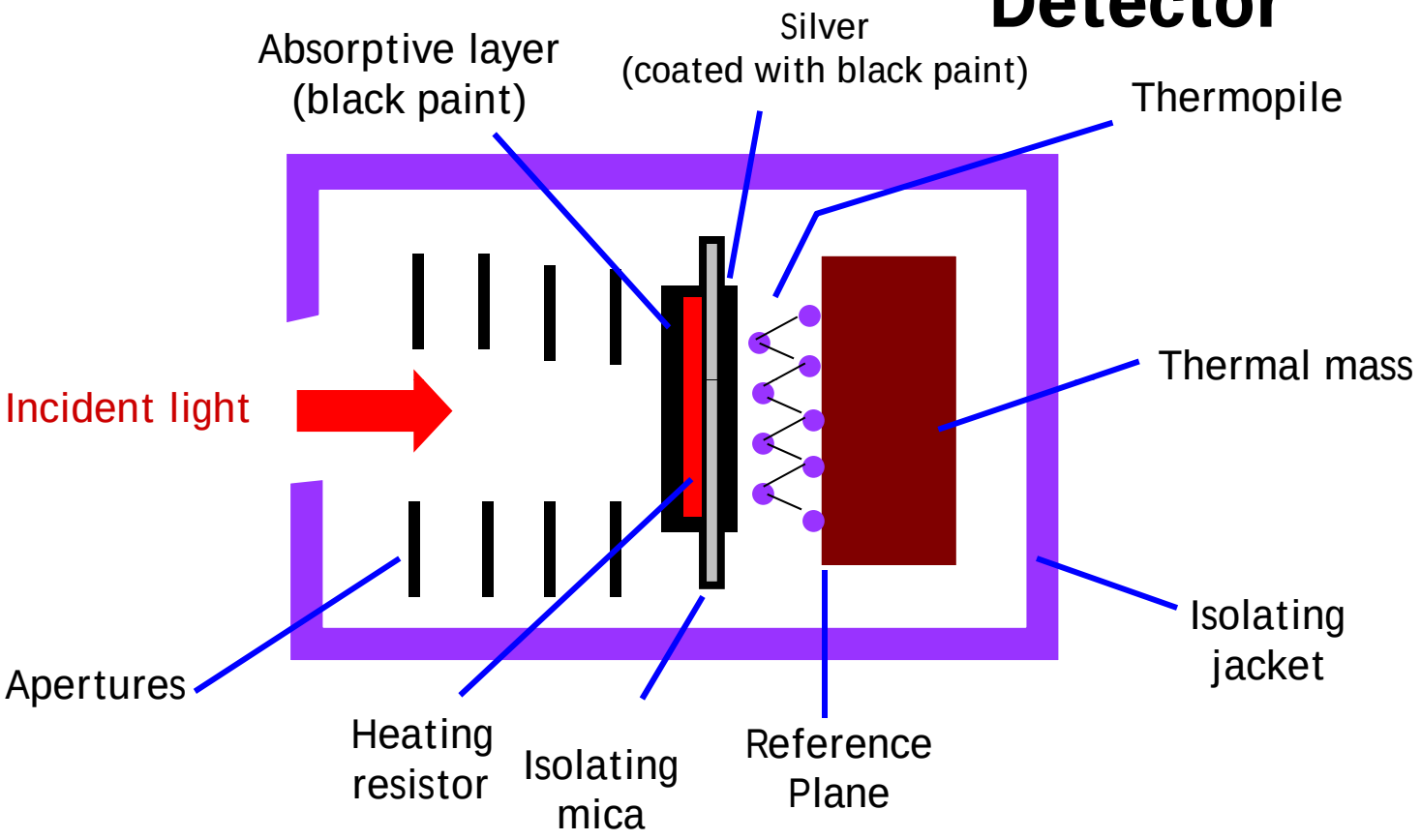
Module Objectives

- Optical power meters
- Oscilloscopes
- Time domain laser chirp measurement
- Optical spectrum analyzers
- RF spectrum analyzers

Optical Power Measurement

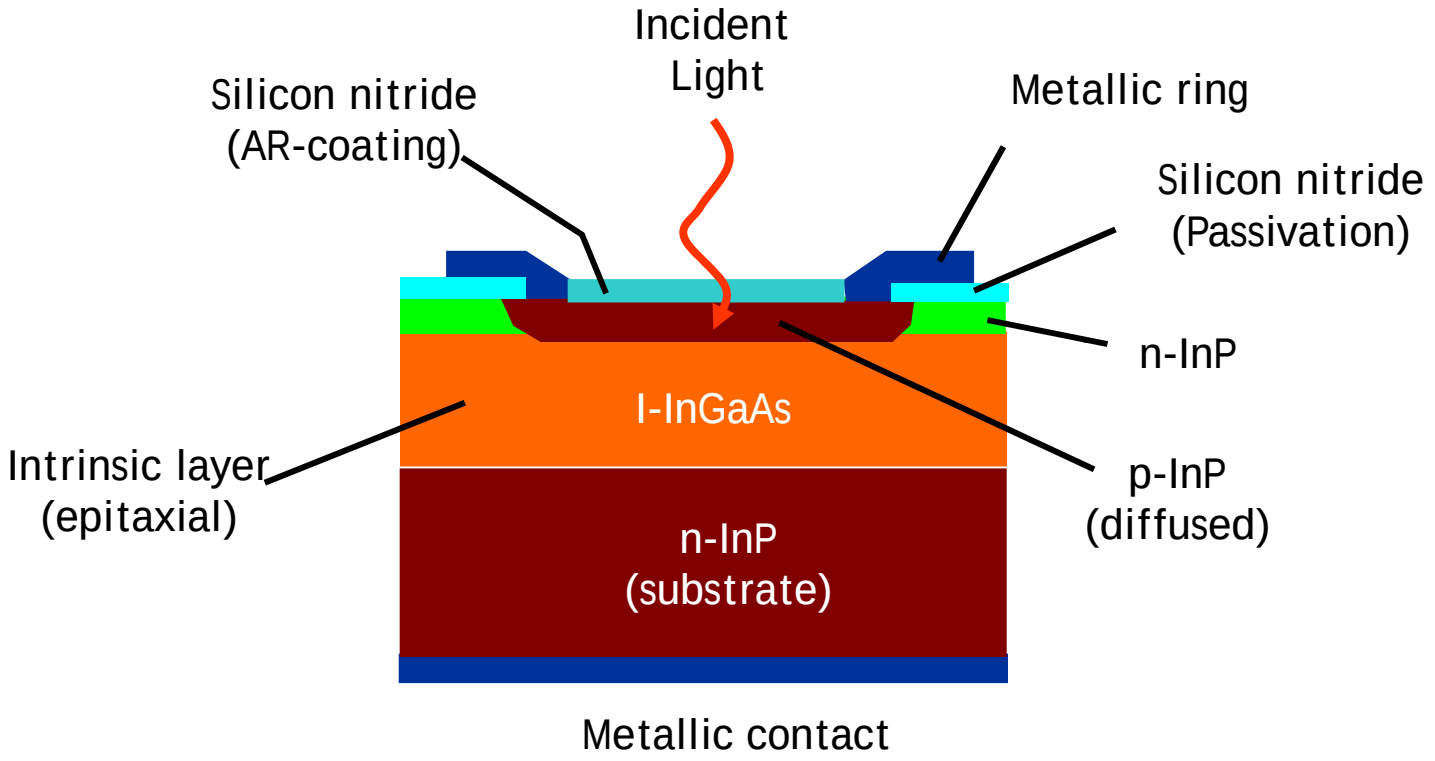
Characteristics	Power meters with thermal detectors	Power meters with photodetector
Wavelength dependence	+ independent + wide range	- dependent - range 2:1
Self-calibration	+ available	- not available (calibration indispensible)
Sensitivity	- very low (typically 10μW)	+ very high (down to less than 1pW)
Accuracy	±1% depending on calibration method	±2% depending on calibration method

Power Meters with Thermal Detector



This detector uses a method called substitution radiometry, which is a self-calibration method, as the heating effect of the light can be compared with that of an electric heater.

Power Meters with Photodetector

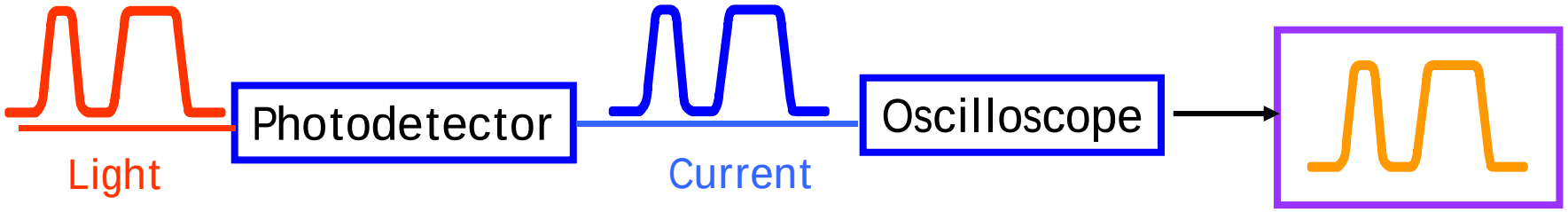


- Can measure power levels down to less than 1pW (-90 dBm)
- Has high frequency response
- Has a strong wavelength dependence

Temporal profile of Laser Output

Measurement Techniques

- A photodetector and oscilloscope (or sampling oscilloscope) combination

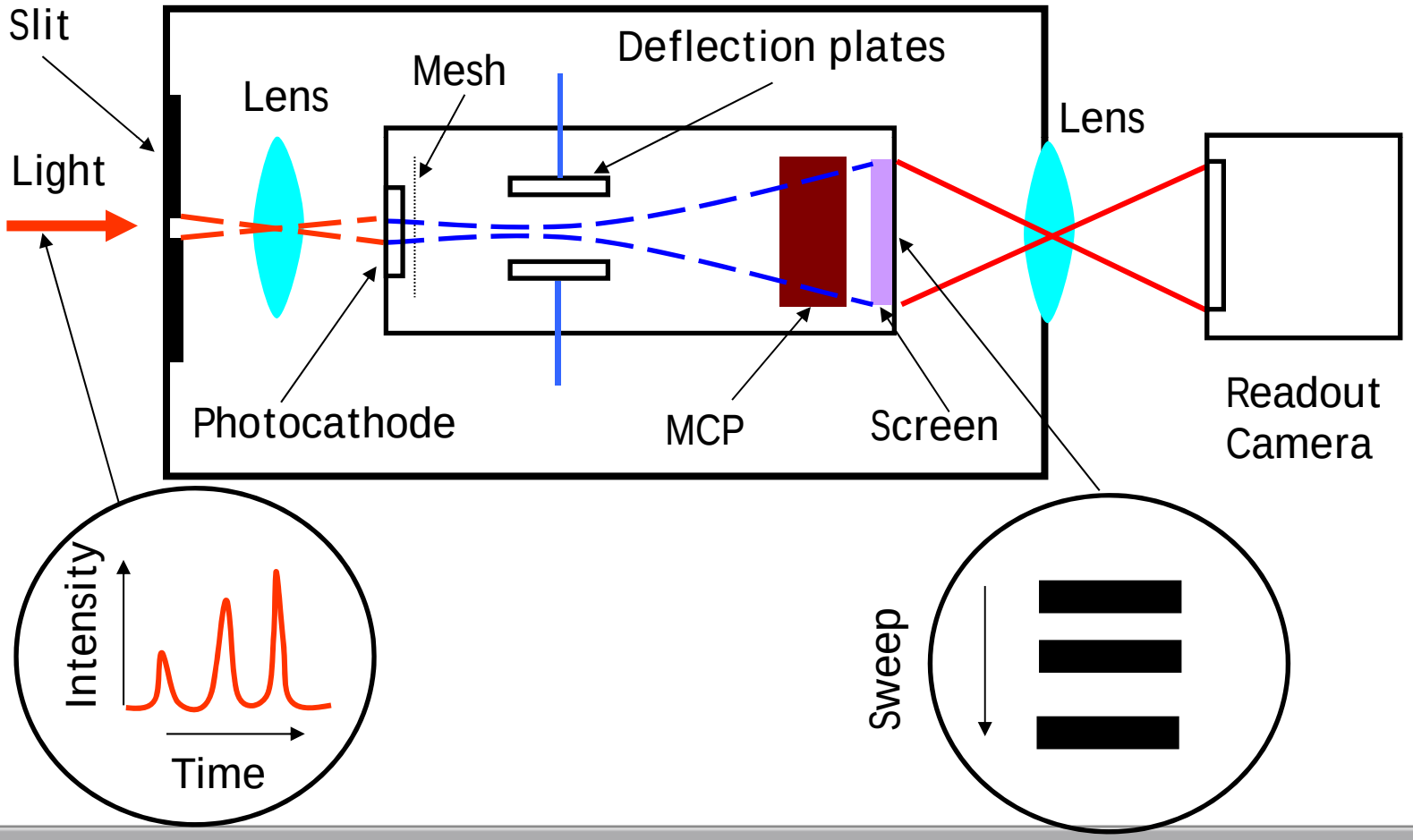


- The time resolution is determined by the detection bandwidth of the photodetector and the rise time of the oscilloscope
  - Photodetector: rise time of 6ps; bandwidth of 60 GHz
  - Oscilloscope: rise time of 7ps; bandwidth of 50 GHz
  - Overall: rise time of 9.2ps; bandwidth of 40 GHz

Temporal profile of Laser Output

Measurement Techniques

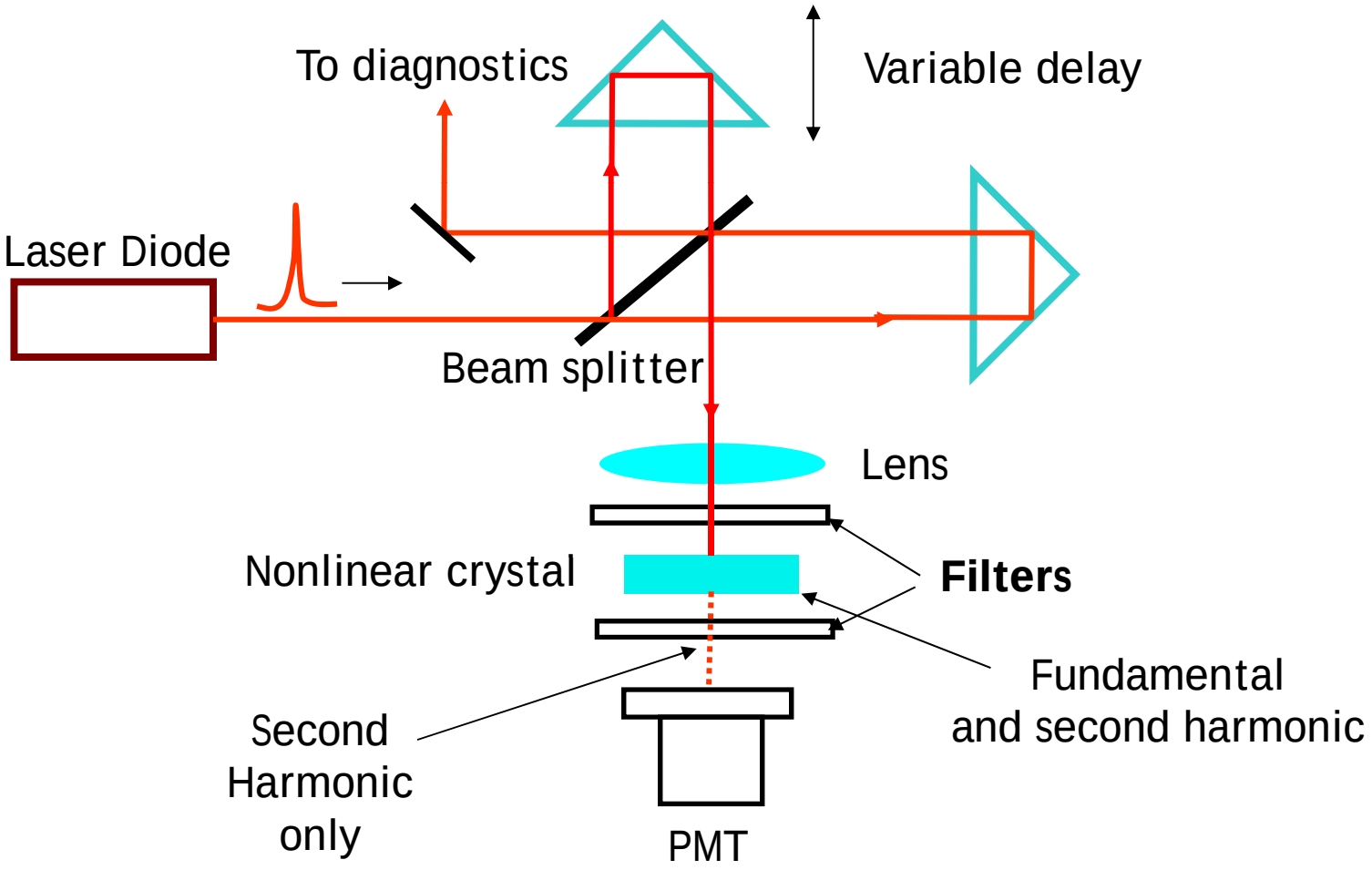
Streak cameras: time resolution of 500 fs



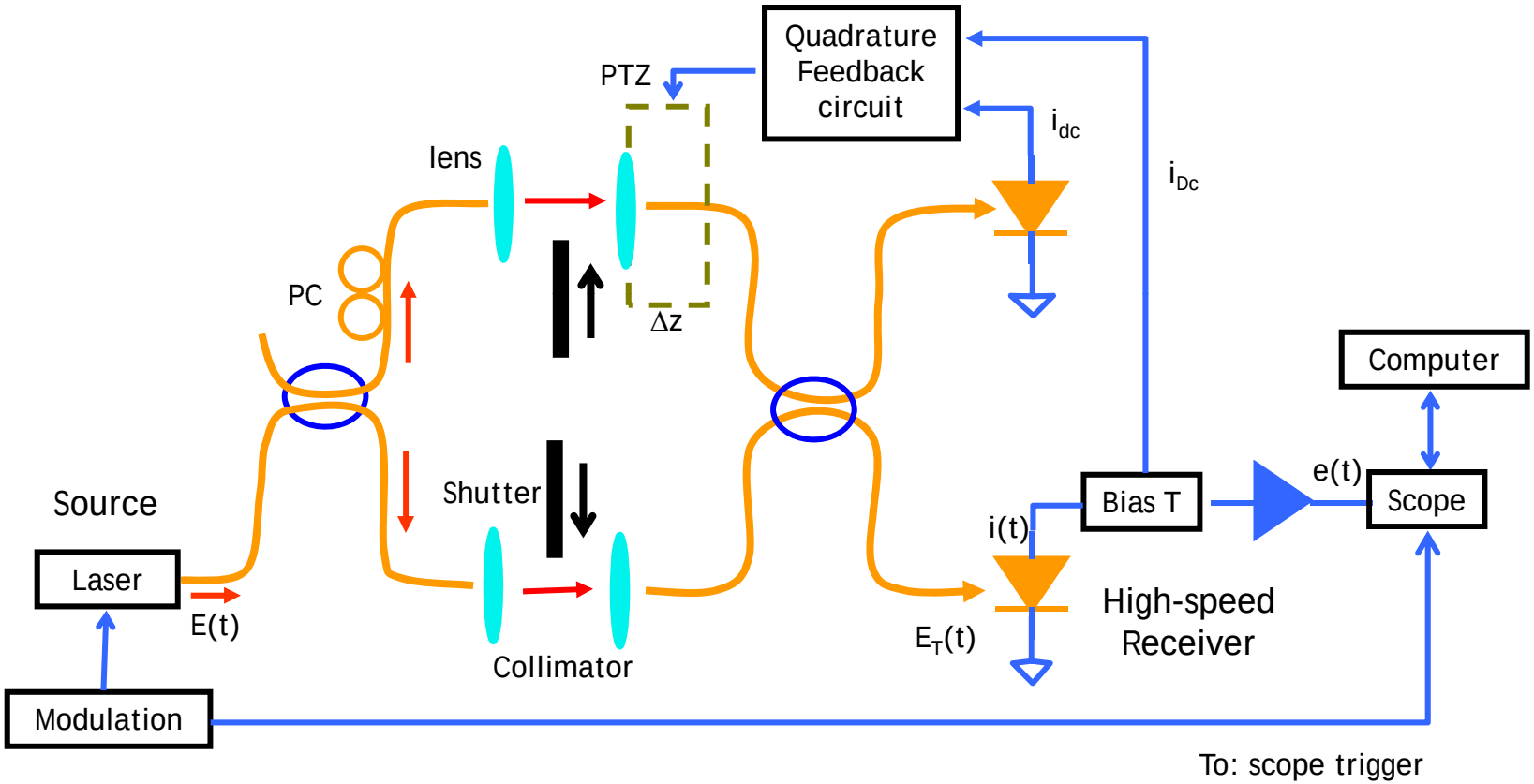
Temporal profile of Laser Output

Measurement Techniques

Autocorrelator: time resolution tens of fs

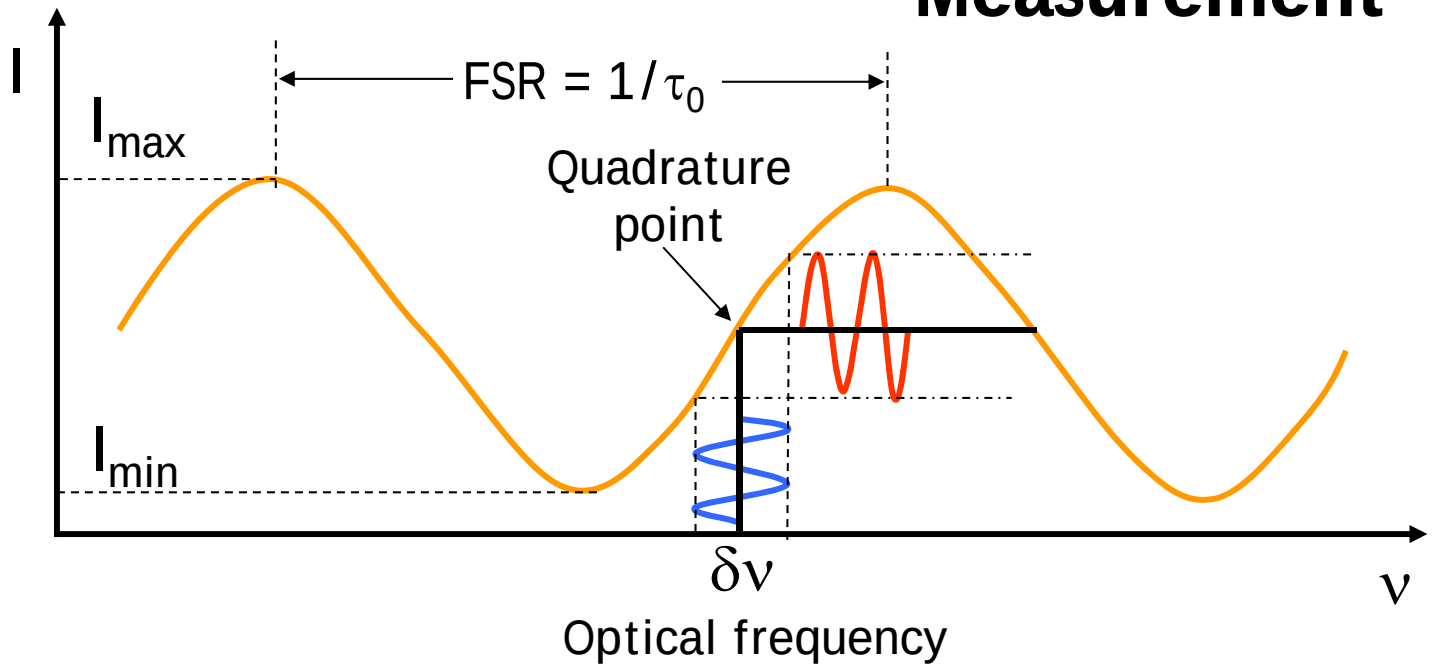


Time-domain Laser Chirp Measurement



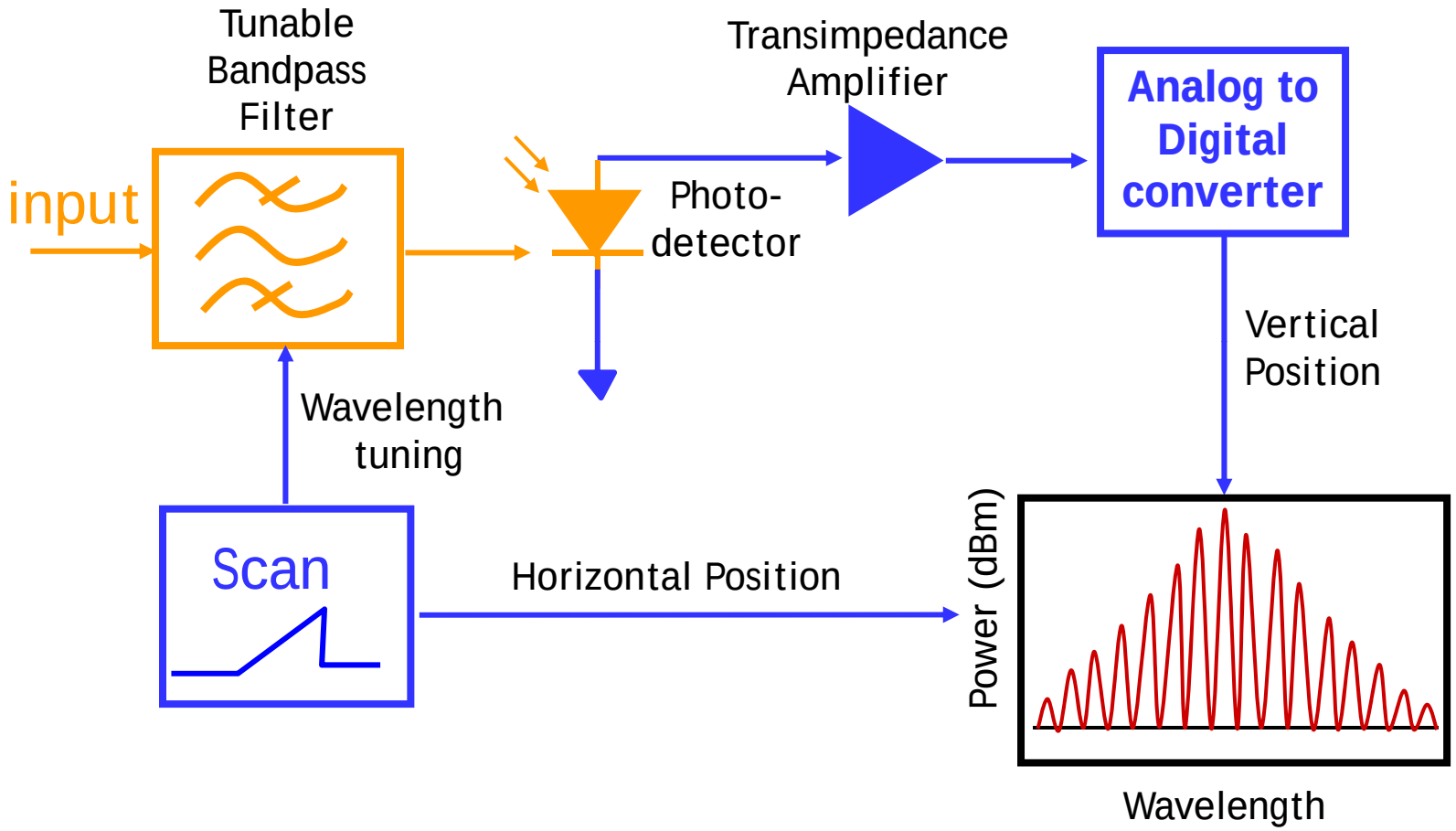
- The time dependence of frequency chirp can be characterized using an optical discriminator.
- The purpose is to convert chirp into intensity variation

Time-domain Laser Chirp Measurement



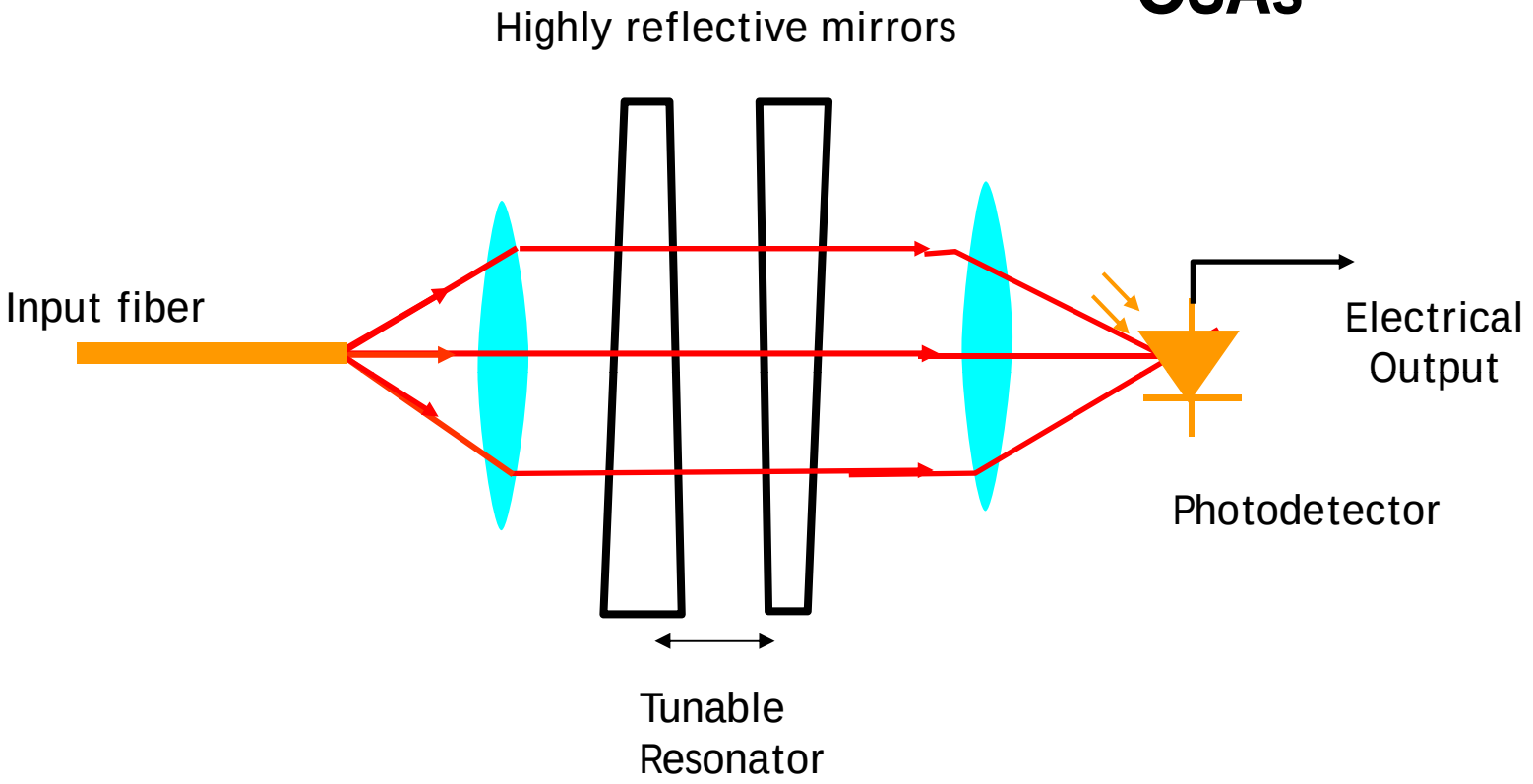
- When the average powers from each of the two interferometer output ports are equal, the interferometer is in quadrature.
- This enables conversion of optical frequency chirp into intensity changes via the linear discriminator slope characteristics.

Optical Spectrum Analyzers



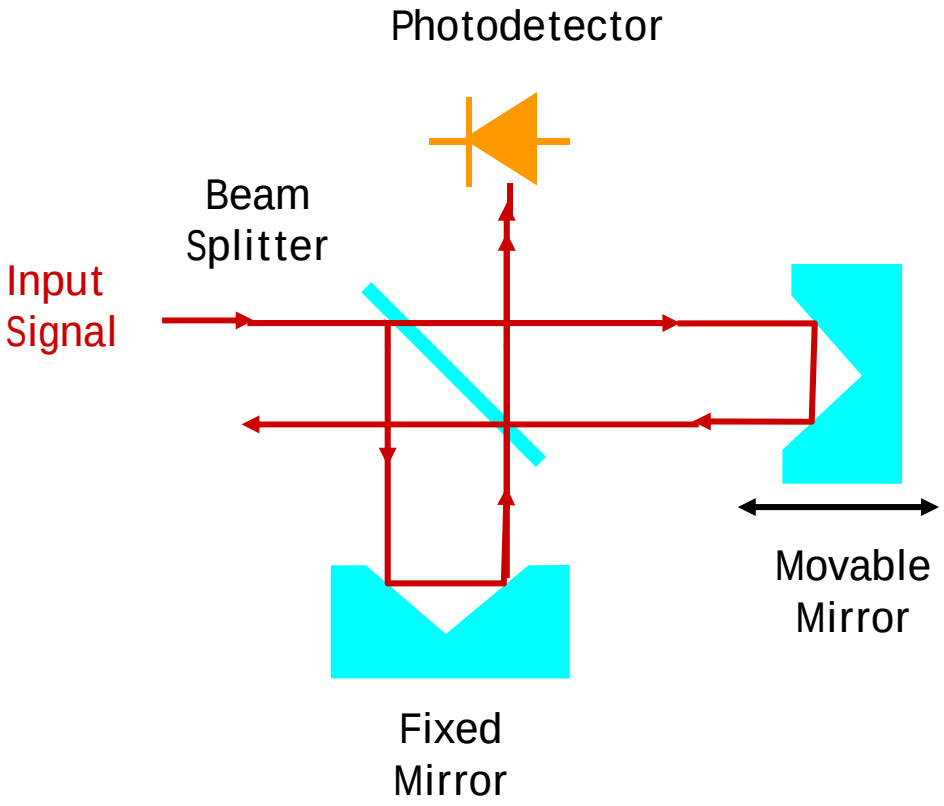
The displayed width of each mode of the laser is a function of the spectral resolution of the tuneable optical filter.

The FP Interferometer-Based OSAs



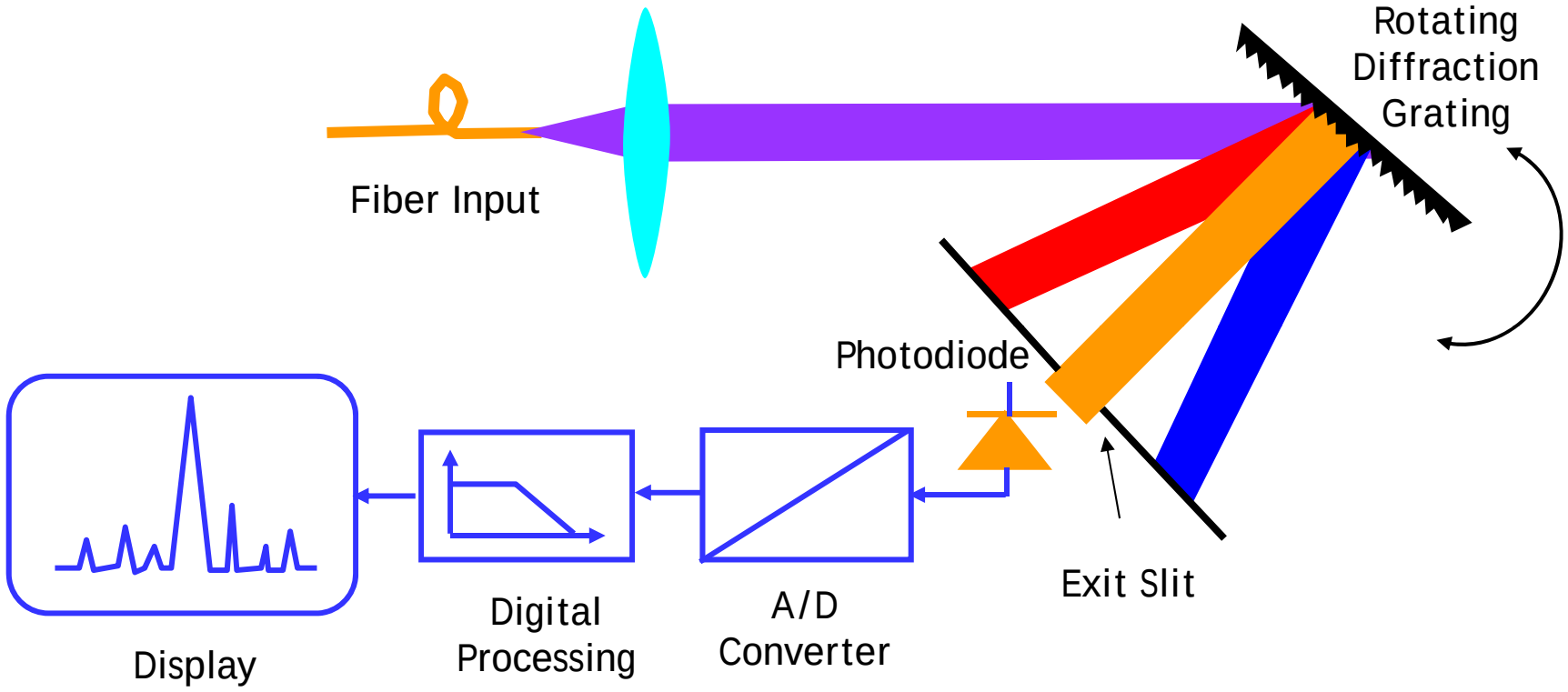
- High spectral resolution (allows laser chirp measurements)
- Simplicity of construction
- Repeated passbands

Interferometer-Based OSA



- High wavelength accuracy
- Displays for power versus wavelength
- Less dynamic range than diffraction-grating-based OSAs

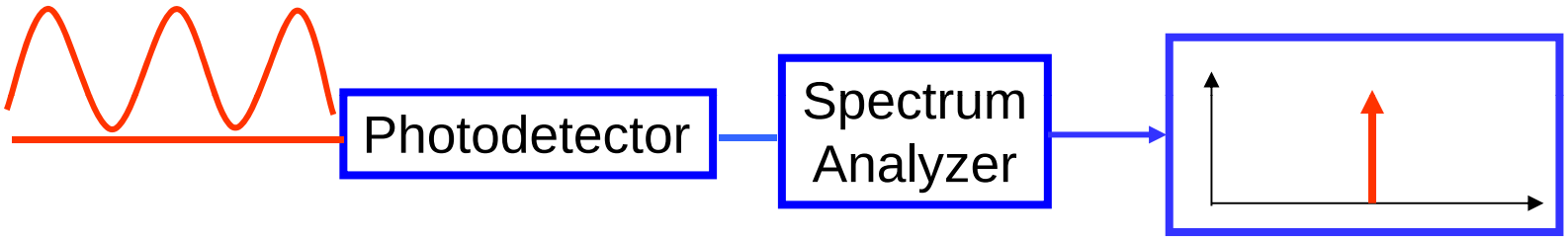
Diffraction-Grating-Based OSA



- The angle of the grating determines the wavelength.
- The size of the input and output apertures together with the size of the beam determines the spectral width of the optical filter.

RF Spectrum Analyzers

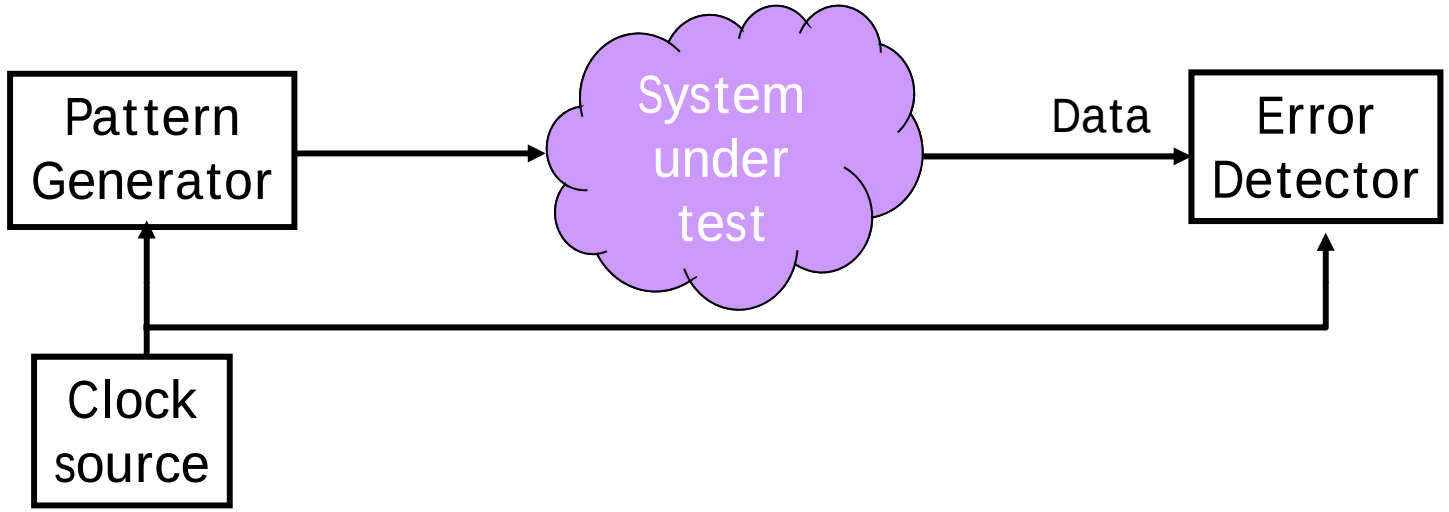
- RF spectrum analyzer indicates the frequency characteristics of a signal



- The resolution bandwidth is determined by the bandwidths of the photodetector and of the spectrum analyzer
  - Photodetector: bandwidth ≤ 60GHz
  - spectrum analyzer: bandwidth ≤ 50GHz

BERT

Basic bit error ratio tester (BERT)



- The pattern is injected into the system under test and received at the error detector's data input
- The error detector includes its own pattern generator that produces an exact replica of the known test pattern
- Each time the received bit differs from the known transmitted bit, an error is logged

Summary

In this module, the following basic photonic measurements were introduced:

- Optical Power Measurement
- Time Domain Measurement Techniques
  - Oscilloscope, Streak Camera, Autocorrelator
  - Laser chirp measurement
- Optical Spectrum Analyzers
- RF Spectrum Analyzers
- BER Test Set

Proceed with the *Interactive Learning Module*