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**Notes for the course of "Fiber Optics"**

# LABORATORY EXPERIENCES

(Academic year 2019/2020)

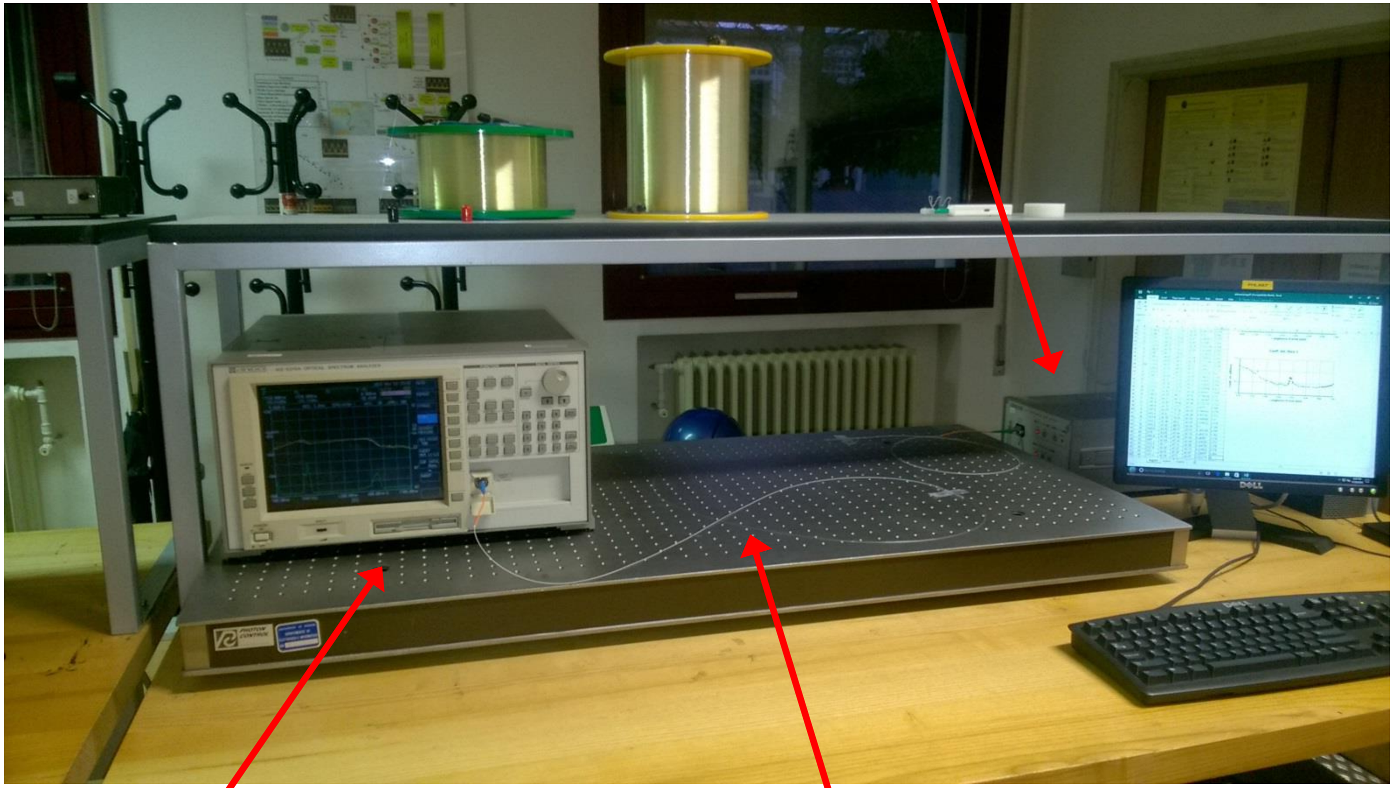
# The Decalogue (of the good student)

1. Do not disconnect patch cords from instruments (unless explicitly instructed to).
2. Cover the connector whenever you are not using it.
3. Do not pat or scratch the side of the fiber bobbins.
4. Do not crush, bend or twist fiber patch cords.
5. Throw the cut pieces of fiber in the trash bin.
6. You break it (with malice), you buy it.
7. You break it (for gross negligence), …
8. Do not shout.
9. Do not run.
10. Do not drink or eat.

11. Enjoy!

# Cut-off frequency and spectral attenuation

Broad-band light source

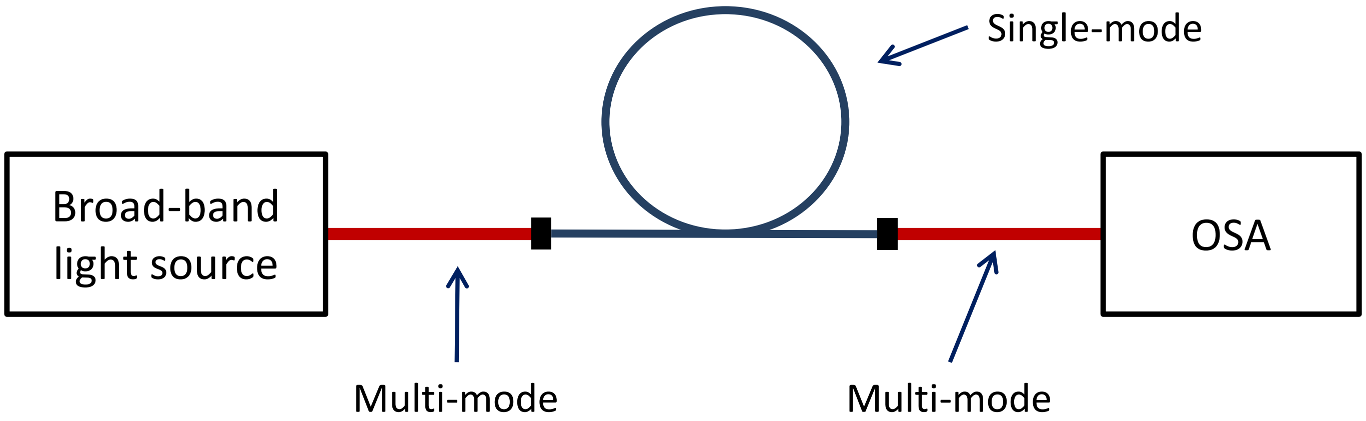


Optical spectrum analyzer (OSA)

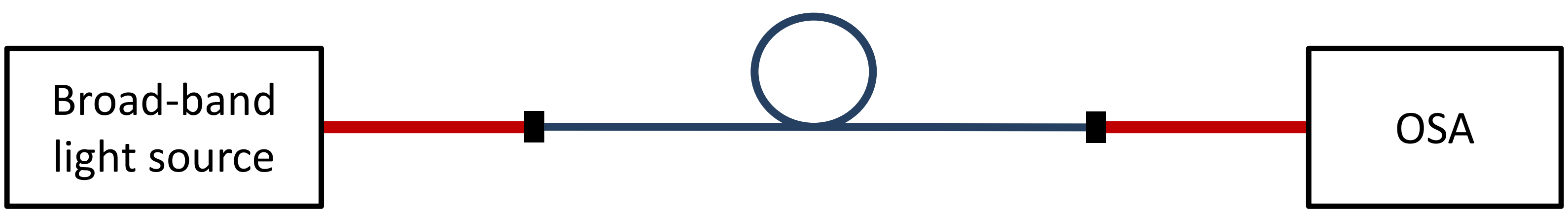
Fiber samples

# Measurement of cut-off frequencies

**Reference measurement**

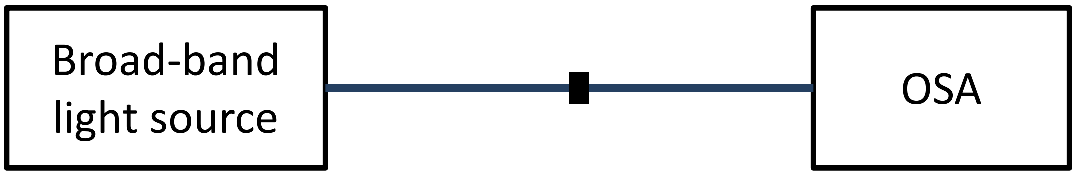



**Measurement of the cut-off frequencies**

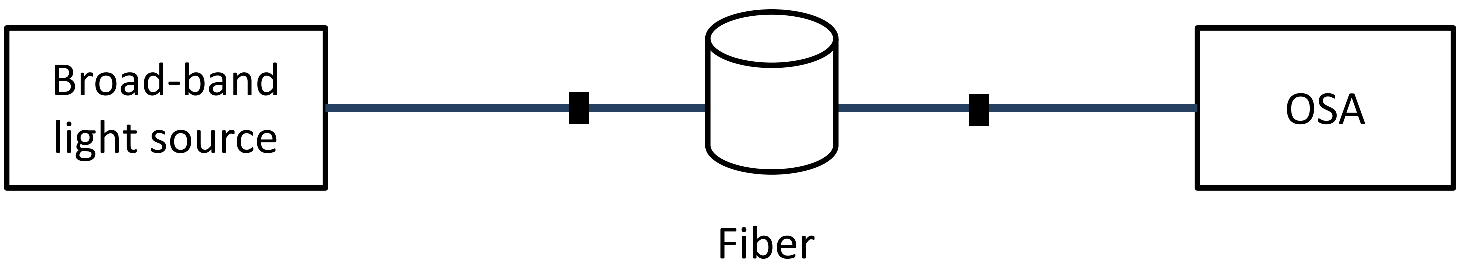


# Spectral attenuation

**Reference measurement**



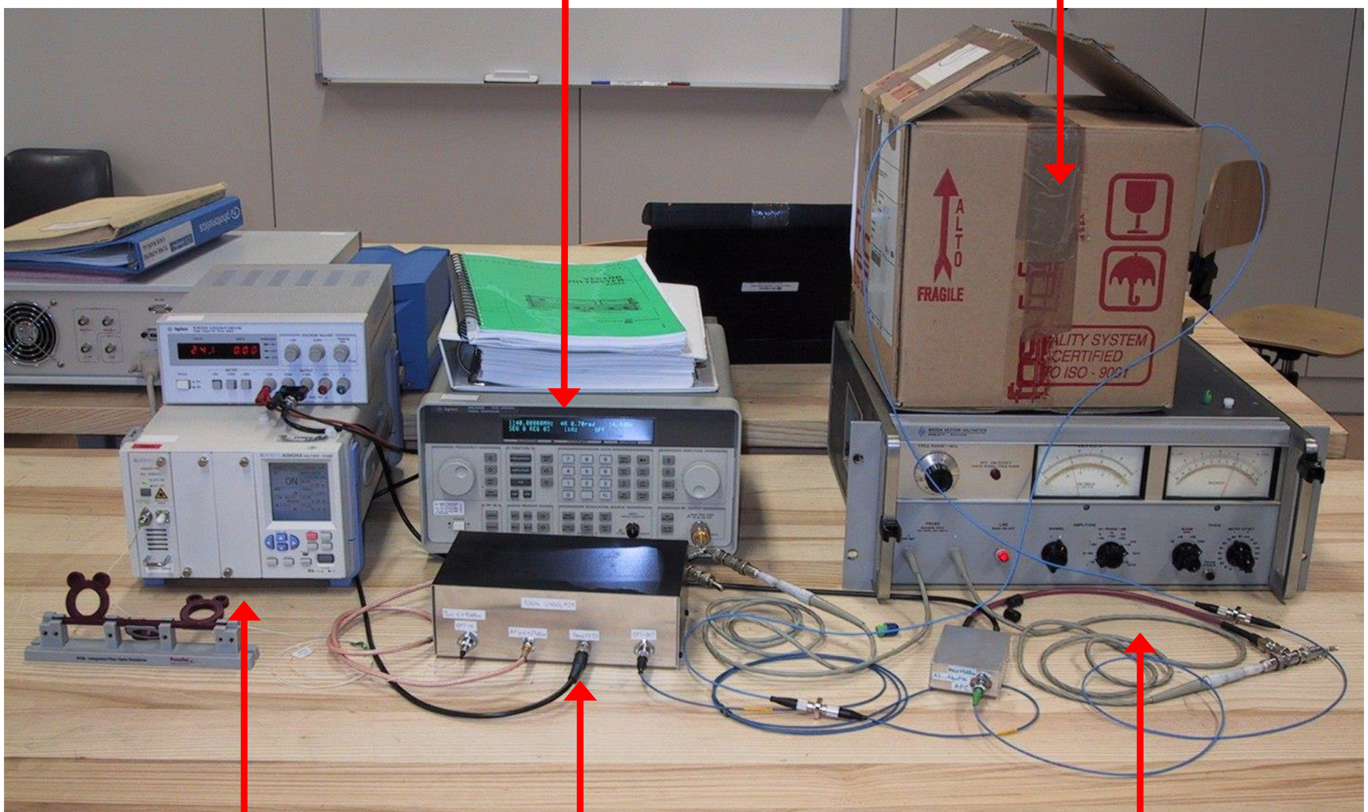

**Attenuation measurement**



# Chromatic dispersion

RF Generator

Fiber




External cavity laser

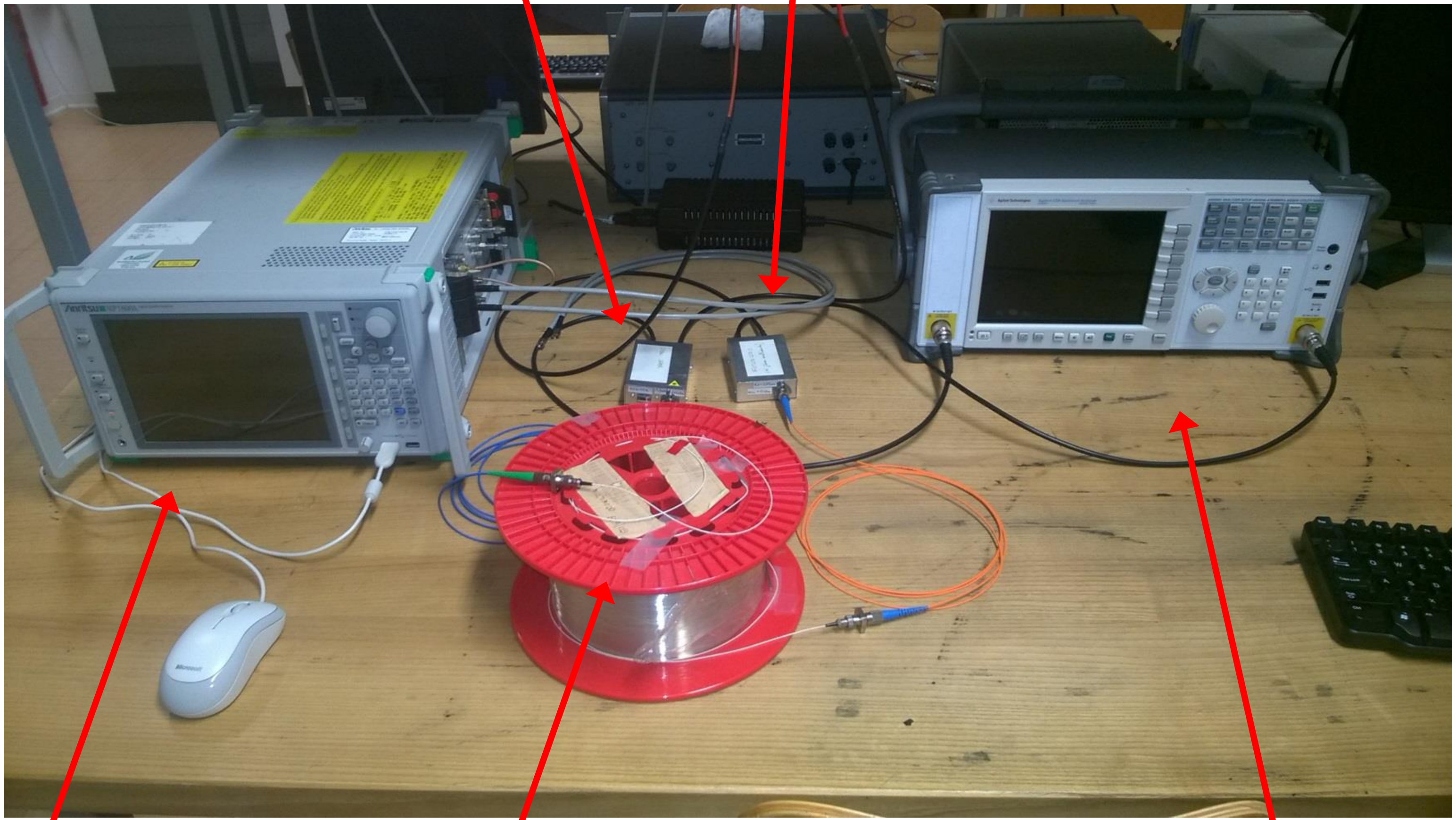
Electro-optic modulator

Vector voltmeter

# Modal dispersion

Laser diode

Photodiode

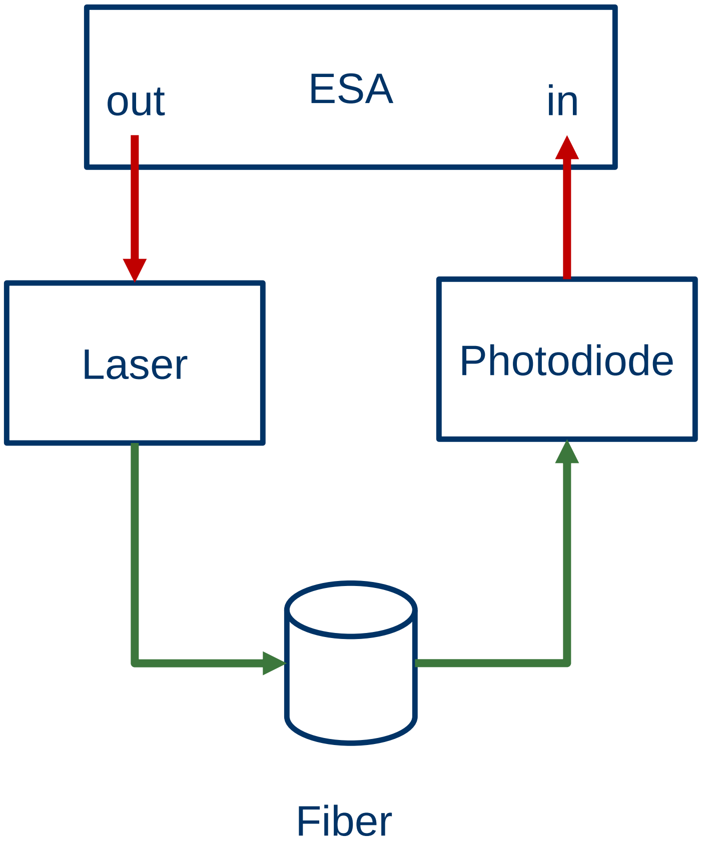


BER tester

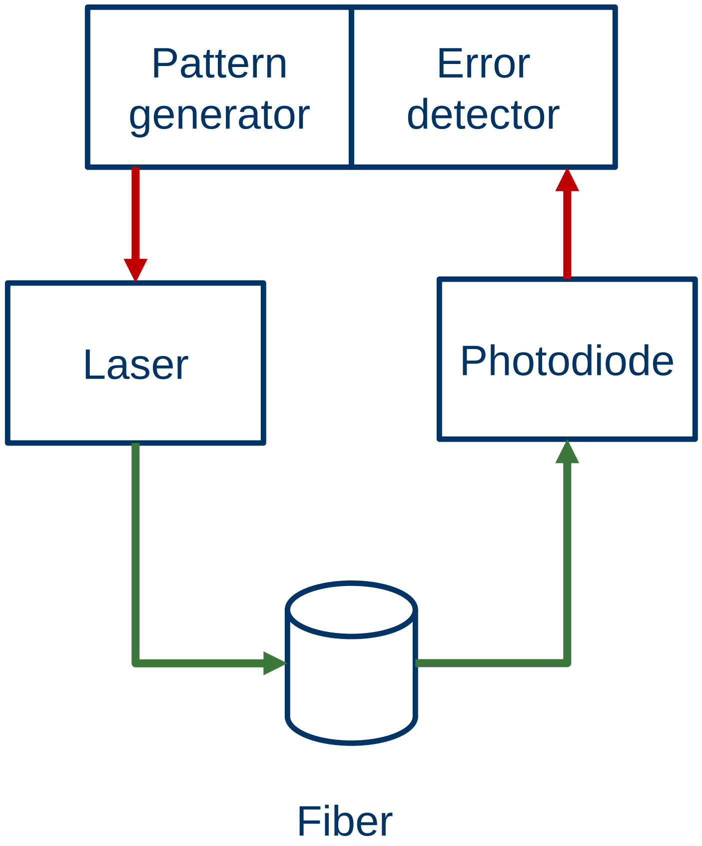
Multimode fiber

Electrical spectrum analyzer

# Modal dispersion

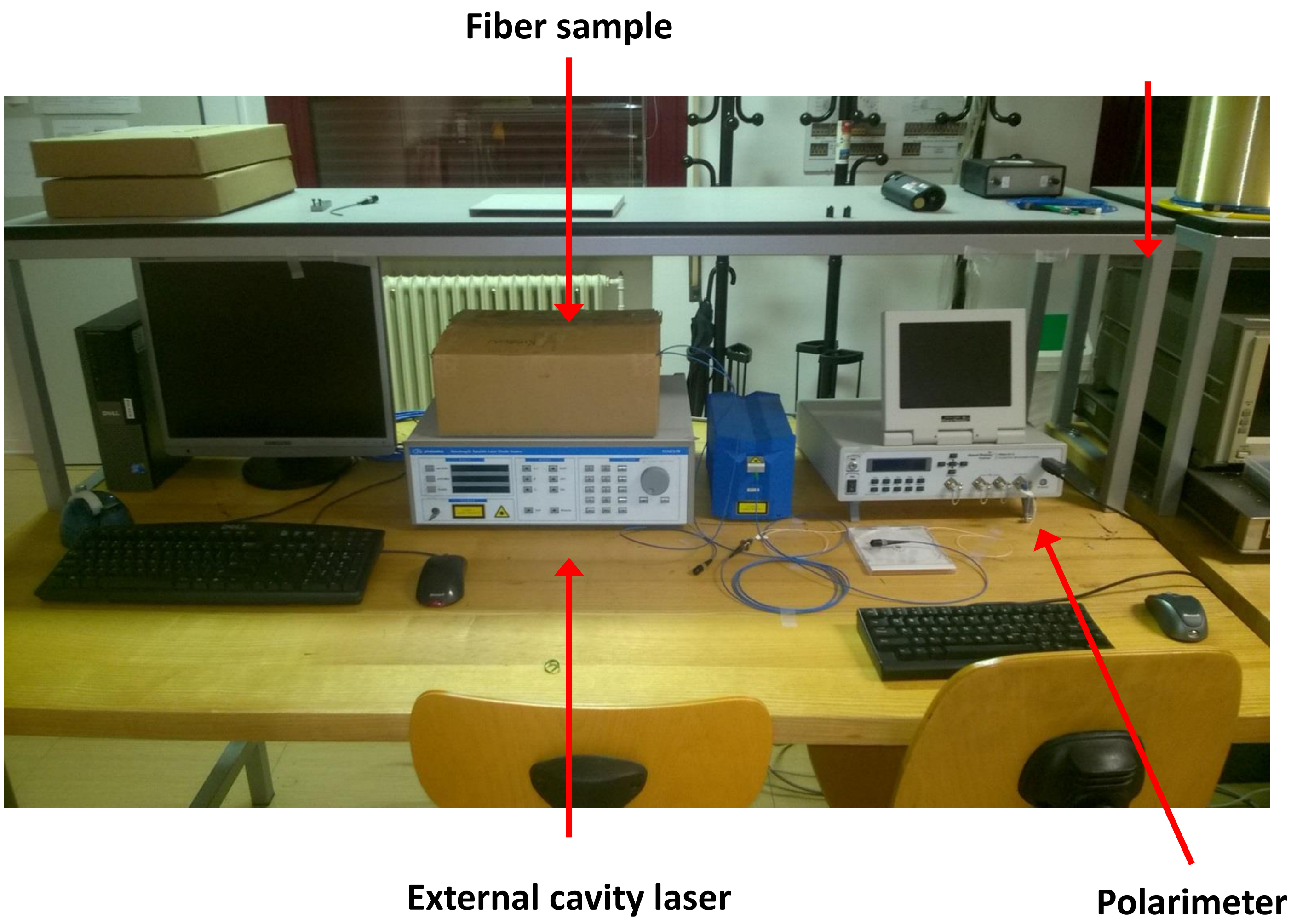



FREQUENCY RESPONSE



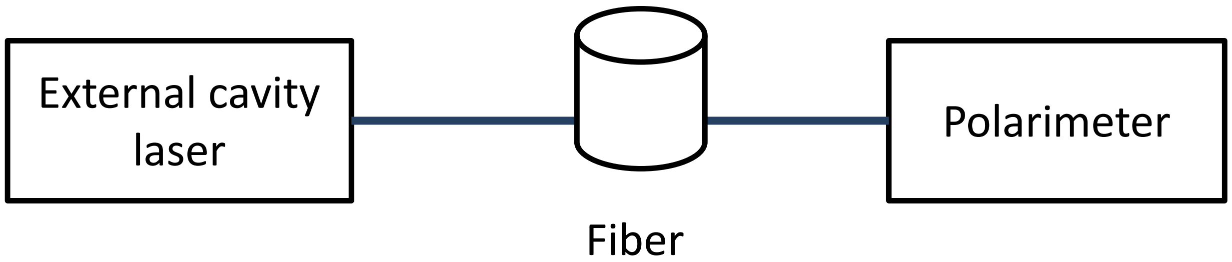

BER MEASUREMENT

# DGD measurement

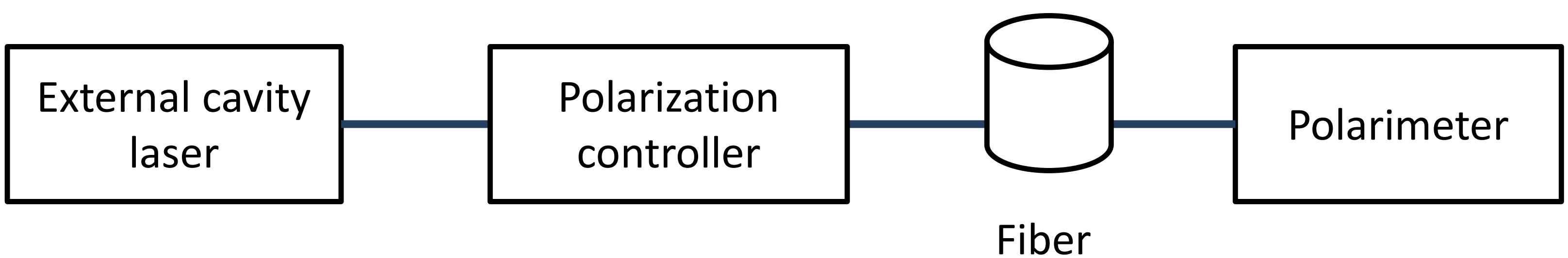


# DGD measurement methods

**Level crossing-rate analysis**




**Mueller matrix method**



# Level crossing-rate analysis

The state of polarization (SOP) transmitted by a fiber depends on frequency according to the following formula:

$$\frac{d\hat{s}}{d\omega} = \overline{\Omega}(\omega) \times \hat{s}(\omega).$$

The level crossing-rate analysis to measure DGD, $\Delta\tau$, is based on the analysis of the function

$$T(\omega) = \frac{1}{2}(1 + \hat{s}(\omega) \cdot \hat{p})$$

which can be calculated from the measured SOP and where $\hat{p}$ is an arbitrary unit vector.

In fact, if the fiber is **polarization maintaining**, the function $T(\omega)$ is periodic with period $2\pi/\Delta\tau$. Therefore, by measuring the period of $T(\omega)$ we can calculate the DGD.

Differently, if the fiber is a **standard telecommunication fiber**, the function $T(\omega)$ is a random process. In this case it can be proved that the mean number of times, $n(\nu)$, that $T(\omega)$ crosses the level $\nu$ per unit frequency band is given by

$$n(\nu) = \frac{\langle\Delta\tau\rangle}{2}\sqrt{\nu(1-\nu)}.$$

# Level crossing rate analysis

Given the function $T(\omega)$ and a set of $M$ levels $\nu_i$ ($i = 1, \dots, M$), the corresponding crossing rate $n(\nu_i)$ can be calculated. From this set of values, the mean DGD can then by estimated by least square analysis, which yield the following formula:

$$\langle \Delta\tau \rangle = \frac{2 \sum_{i=1}^{M} n(\nu_i) \sqrt{\nu_i(1-\nu_i)}}{\sum_{i=1}^{M} \nu_i(1-\nu_i)}$$

In the special case in which only the level $\nu = 1/2$ is considered, the formula simplifies to

$$\langle \Delta\tau \rangle = 4\, n(1/2).$$