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# Desenvolvimento de um WebLab para Estudo e Caracterização de Sistemas WDM

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Co-orientador: Dr. Eunézio de Souza

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# Sumário.

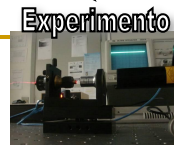
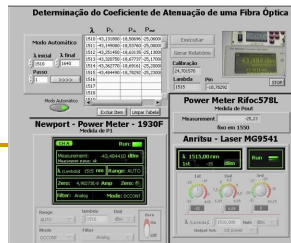
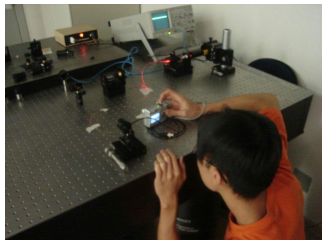
- Motivação e Objetivos
  - Estrutura Geral do WebLab
  - Integração do WebLab ao MOODLE
  - Sistemas WDM
  - Simulação de Sistemas WDM em VPI
  - Experimento para Caracterização de Sistemas WDM
  - Instrumentos Virtuais – LabVIEW
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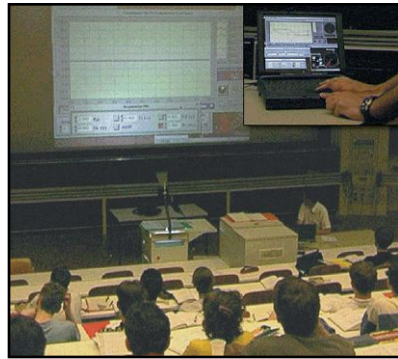
# Motivação e Objetivos.

- O advento da Internet e o desenvolvimento das Tecnologias de Informação e Comunicação (TIC's) geraram novos espaços para a comunicação e colaboração entre grupos de pessoas localizadas em regiões geograficamente distintas.
  - **WebLabs** são ambientes/laboratórios distribuídos que permitem o acesso e controle remoto via Internet de experimentos reais com a sensação de presença.
  - O Objetivo deste trabalho é o desenvolvimento de um WebLab para estudo e caracterização de um sistema WDM
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# Estrutura do WebLab.



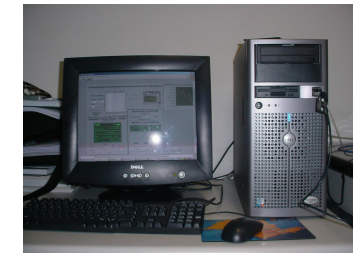
# Estrutura do WebLab.



**Servidor Web**



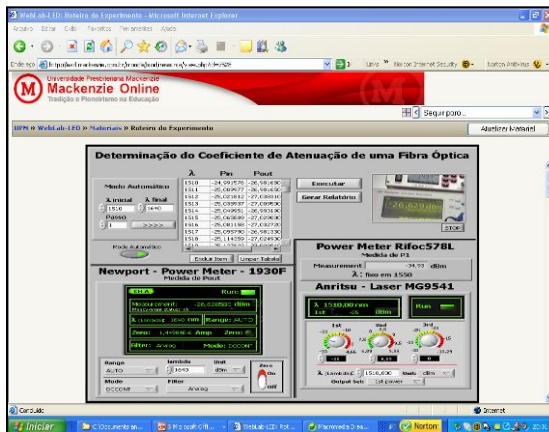
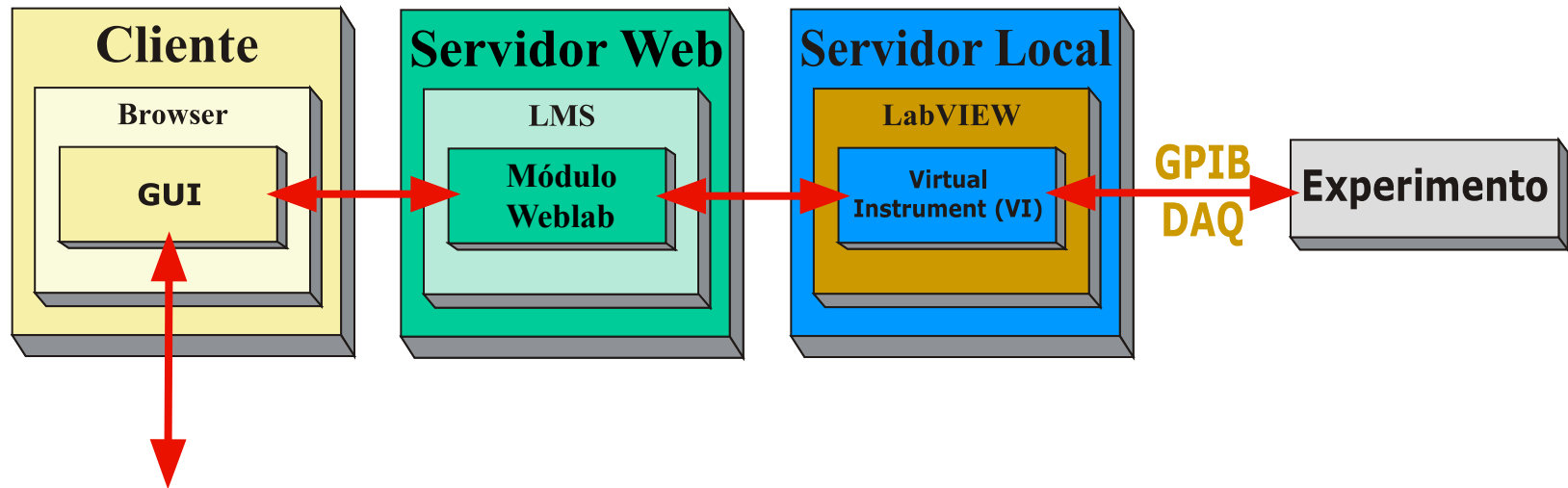
**Servidor Local**



**GPIB/DAQ**



# Arquitetura Cliente/Servidor Dupla.



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# Integração do WebLab ao MOODLE.

- O WebLab foi integrado a um ambiente virtual de ensino-aprendizagem, implementado através do programa MOODLE.



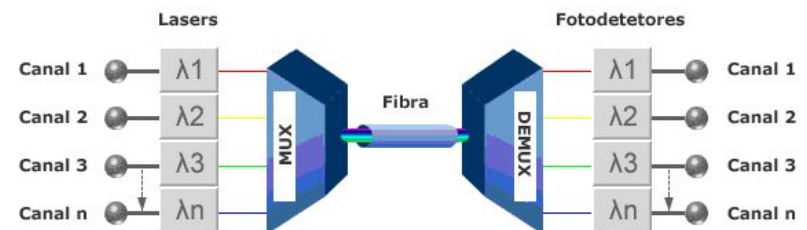
- Módulo WebLab: aplicativos desenvolvidos com base em linguagens suportadas pelo MOODLE (PHP, XML, Java, Javascript, etc.).
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# Sistemas WDM.

- Necessidade por alta capacidade em sistemas de Comunicação.
- Tecnologias existentes OTDM e WDM.
- Fornecer estudo do comportamento de um sistema WDM de dois canais.

## Componentes para sistemas WDM

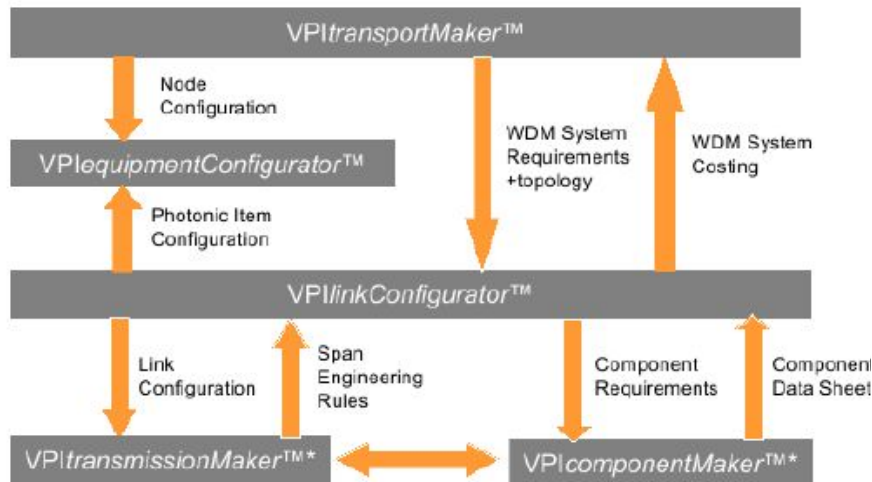
- Transmissores Ópticos
- Moduladores
- Fibras Ópticas
- Amplificadores Ópticos
- Receptores Ópticos
- Multiplexadores e Demultiplexadores
- Acopladores, Circuladores e Isoladores.



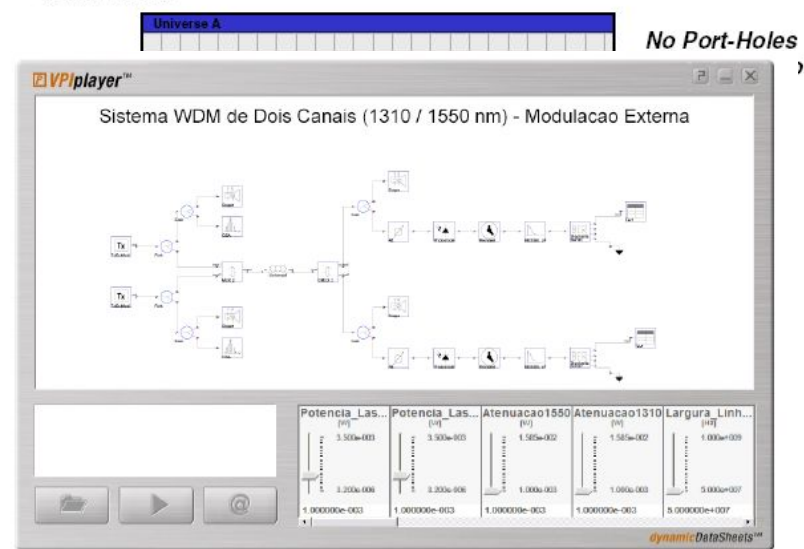


# Simulação de Sistemas WDM em VPI.

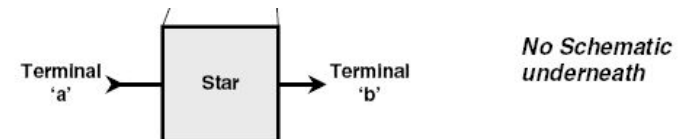
- Componentes do VPI
- Desenvolvimento Modular em VPI
- *Dynamic dataSheet (DDS)*



## Universe

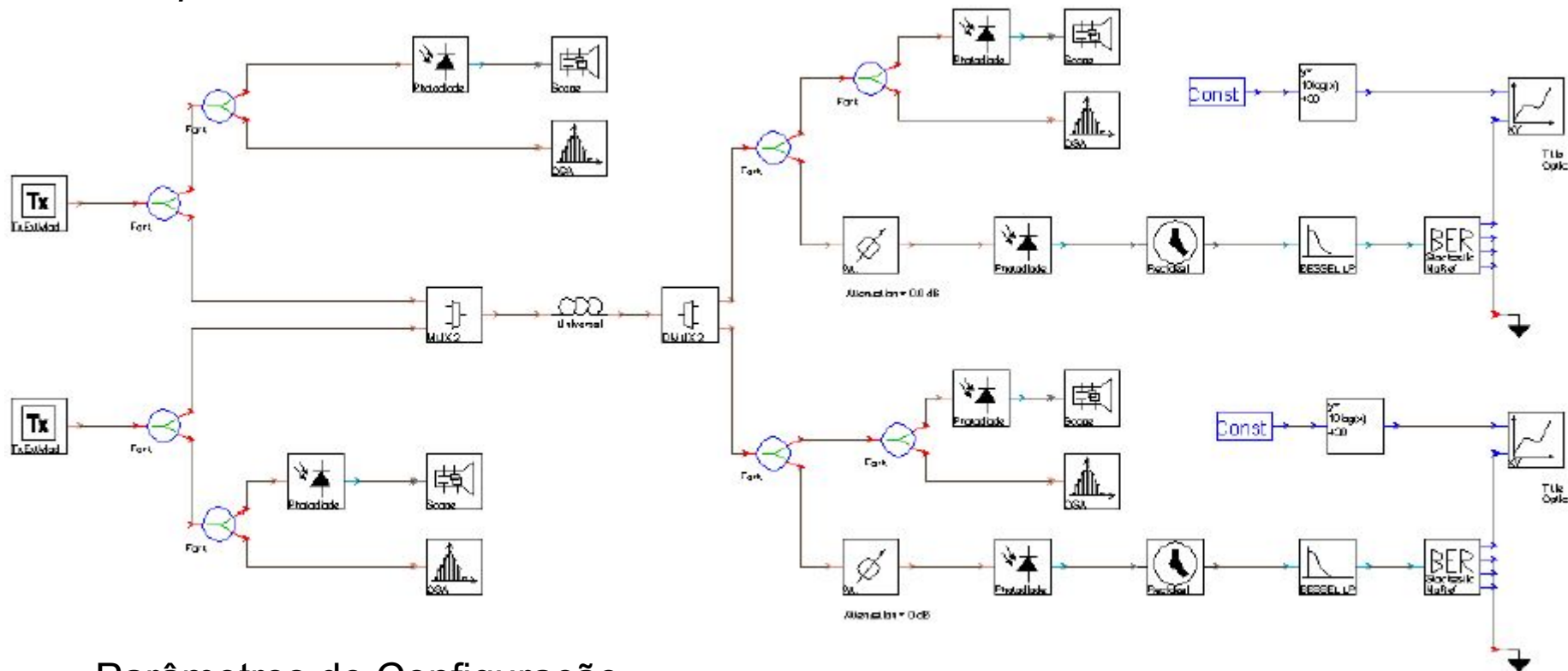


## Star



# Simulação - VPI

## ■ Setup do VPI



## ■ Parâmetros de Configuração

Canal (nm)	Coeficiente de Atenuação (dBm/km)	Coeficiente de Dispersão (ps/nm.km)
1310	0,35	0,22
1550	0	17,38

# Simulação - VPI

Foram realizadas simulações com o objetivo de analisar a BER do sistema nos seguintes casos:

- BER em função da Potência do Laser para vários Comprimentos
- BER em função da Largura do Laser para vários Comprimentos
- BER em função da Potência Recebida (*ROP*) para várias Taxas de Bits
- BER em função da Comprimento da Fibra para várias Taxas de Bits
- BER em função da Taxa de Bits para várias Larguras

A BER é definida como a razão entre o número de bits recebidos errados  
(*n*)  
e o número total de bits transmitidos (*m*).

$$BER = \frac{n}{m}.$$

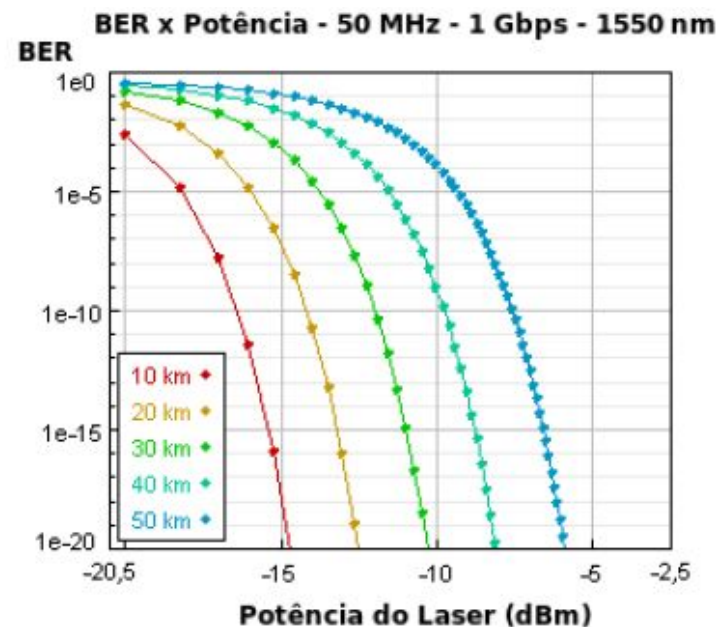
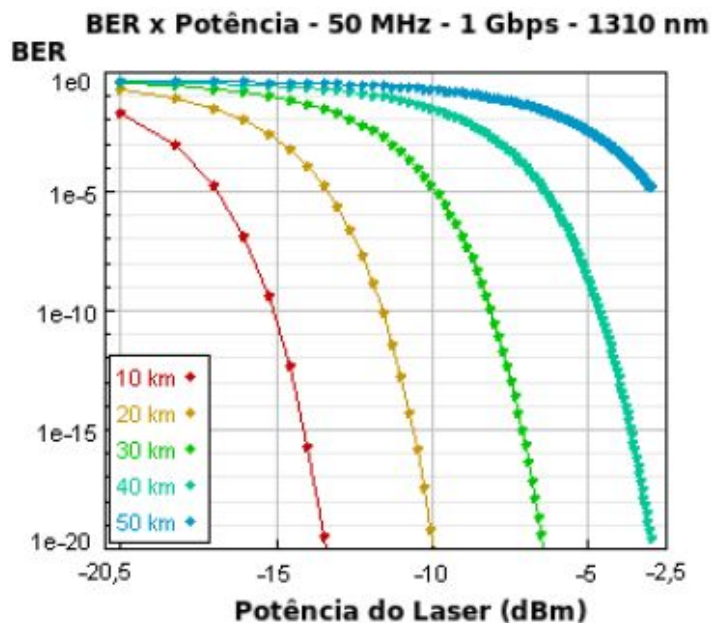
# BER em função da Potência do Laser para vários Comprimentos

Parâmetros fixos/alterados (**negrito**):

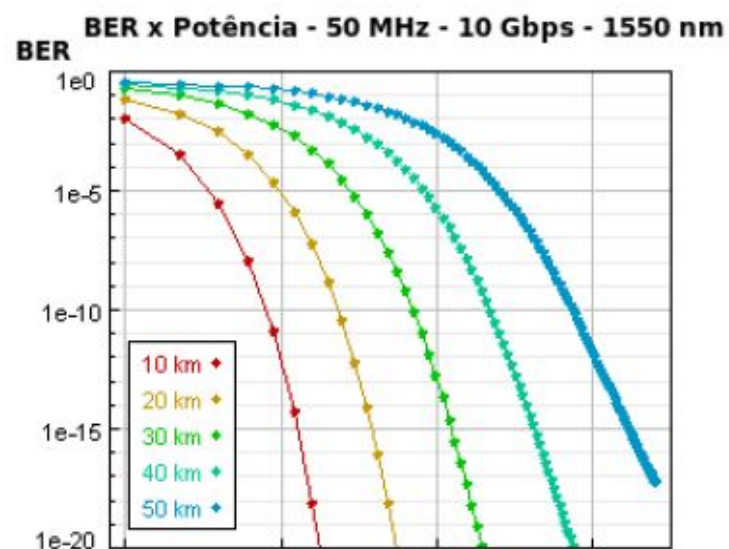
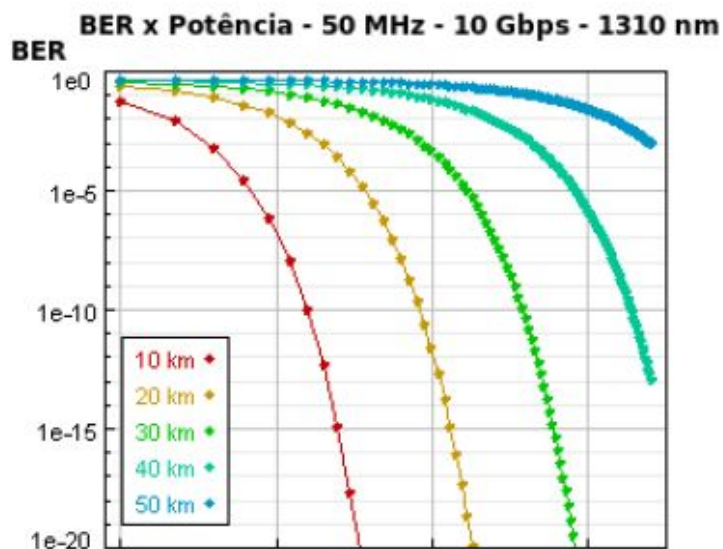
Parâmetros	Valores
<b>Largura do Laser 1310 nm</b>	<b>50 MHz e 1 GHz</b>
<b>Largura do Laser 1550 nm</b>	<b>50 MHz e 1 GHz</b>
<b>Potência Laser</b>	<b>0,01 mW até 0,5 mW (55 pontos)</b>
<b>Taxa de Bit</b>	<b>1 Gbps e 10 Gbps</b>
Atenuação de Entrada 1310 nm	0 dBm
Atenuação de Entrada 1550 nm	0 dBm
<b>Comprimento da Fibra</b>	<b>10 até 50 km (5 curvas)</b>
Perda por Inserção	1,3 dBm
Atenuação da Fibra 1310nm	0,35 dBm/km
Atenuação da Fibra 1550nm	0,22 dBm/km
Dispersão 1310 nm	0 ps/nm.km
Dispersão 1550 nm	$17,38 \cdot 10^{-6}$ ps/nm.km

- BER diminui com a potência
- O canal de 1550 nm apresenta melhor desempenho
- BER aumenta; quando passa de 1 Gbps para 10 Gbps
- BER aumenta; quando passa de 50 MHz para 1 GHz (ambos canais)

1 Gbps



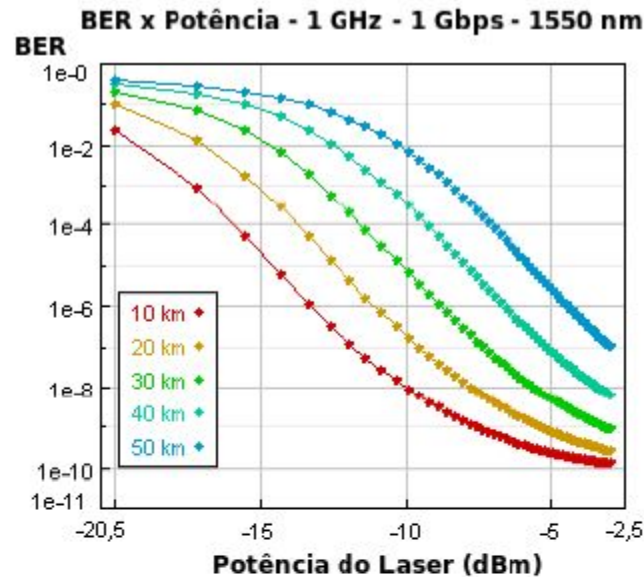
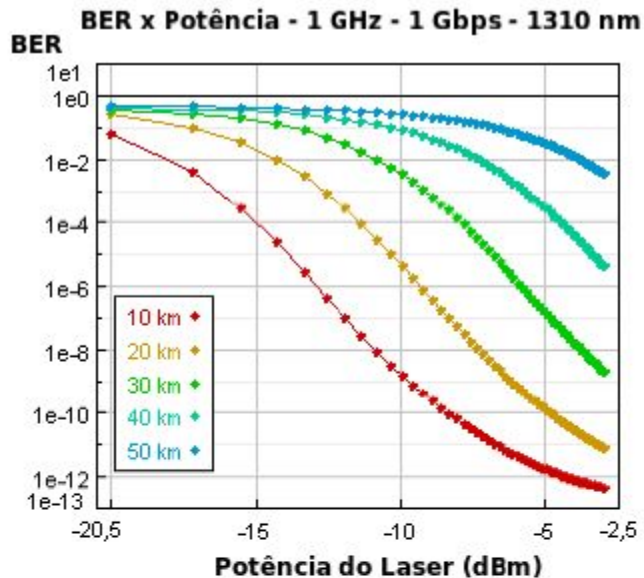
10 Gbps



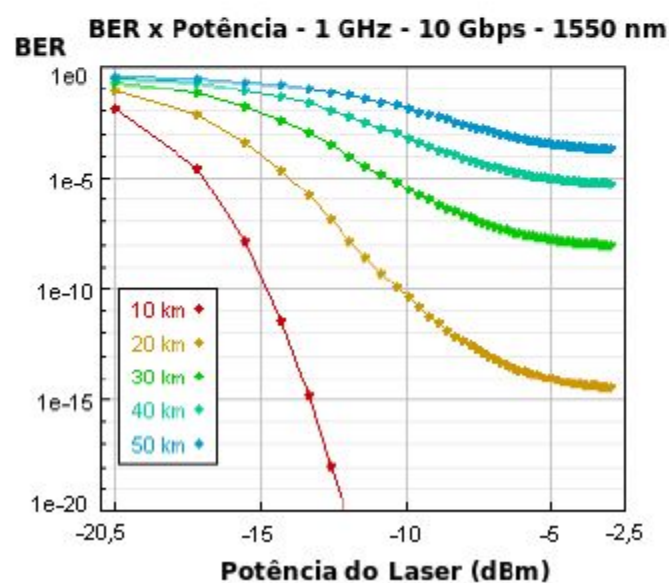
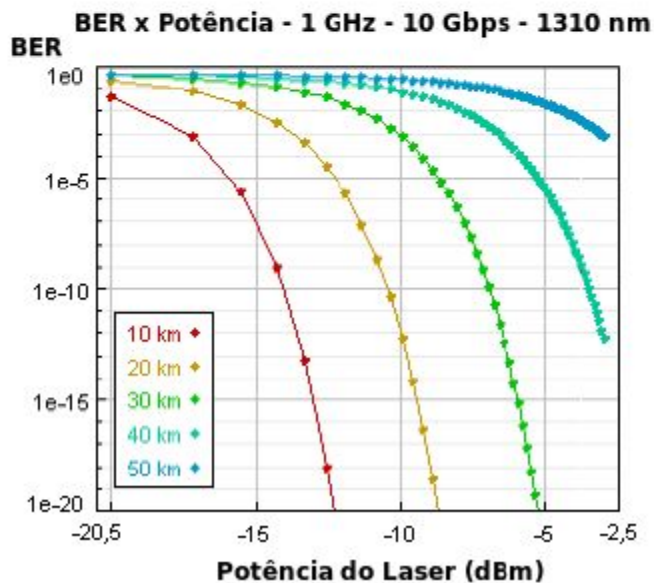
1310 nm

1550 nm

1 Gbps



10 Gbps



1310 nm

1550 nm



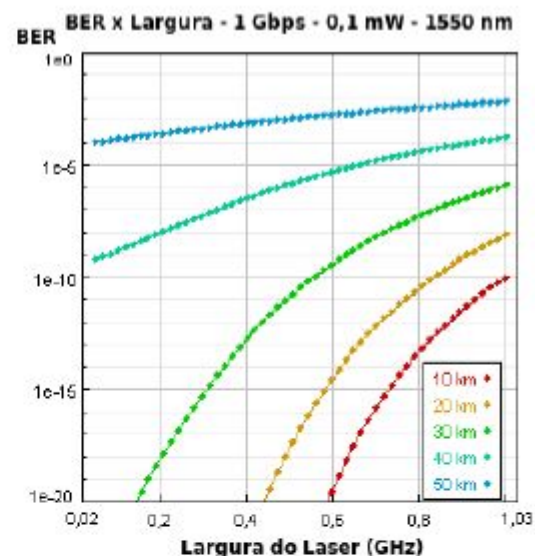
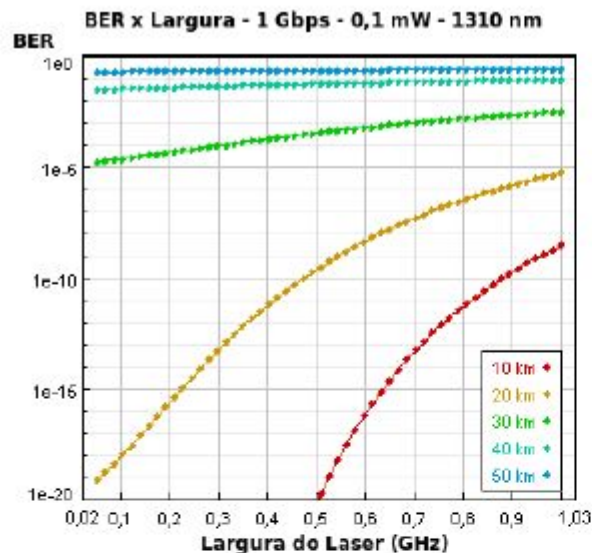
# BER em função da Largura do Laser para vários Comprimentos

Parâmetros fixos/alterados (negrito):

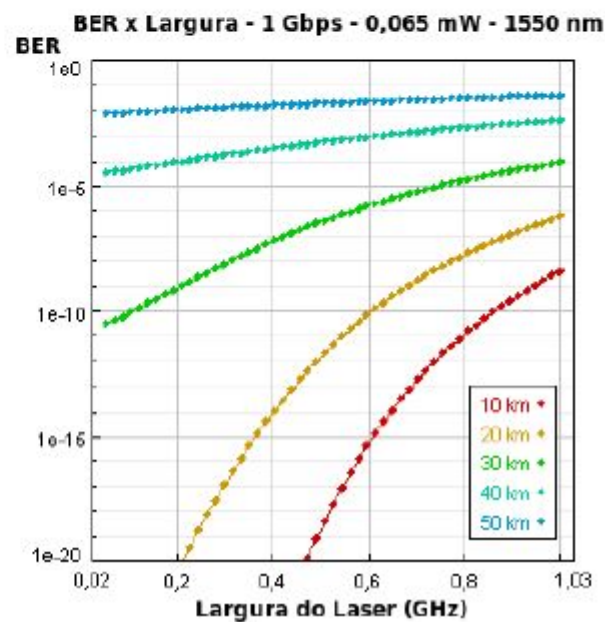
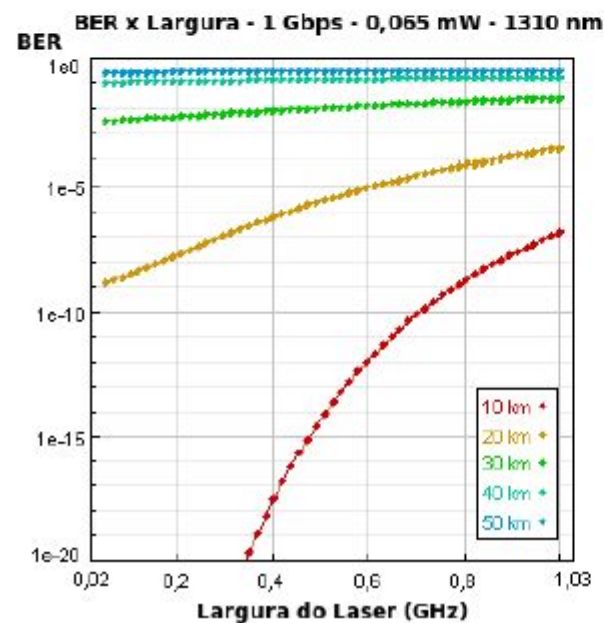
Parâmetros	Valores
<b>Largura do Laser 1310 nm</b>	<b>50 MHz até 1 GHz (55 pontos)</b>
<b>Largura do Laser 1550 nm</b>	<b>50 MHz até 1 GHz (55 pontos)</b>
<b>Potência Laser</b>	<b>0,1 mW e 0,065 mW</b>
<b>Taxa de Bit</b>	<b>1 Gbps e 10 Gbps</b>
Atenuação de Entrada 1310 nm	0 dBm
Atenuação de Entrada 1550 nm	0 dBm
<b>Comprimento da Fibra</b>	<b>10 até 50 km (5 curvas)</b>
Perda por Inserção	1,3 dBm
Atenuação da Fibra 1310nm	0,35 dBm/km
Atenuação da Fibra 1550nm	0,22 dBm/km
Dispersão 1310 nm	0 ps/nm.km
Dispersão 1550 nm	$17,38 \cdot 10^{-6}$ ps/nm.km

- BER aumenta com a largura do laser
- BER diminui para; quando passa de 1 Gbps para 10 Gbps
- A atenuação é o fator limitante; sempre maior para 1310 nm

0,1 mW



0,065 mW

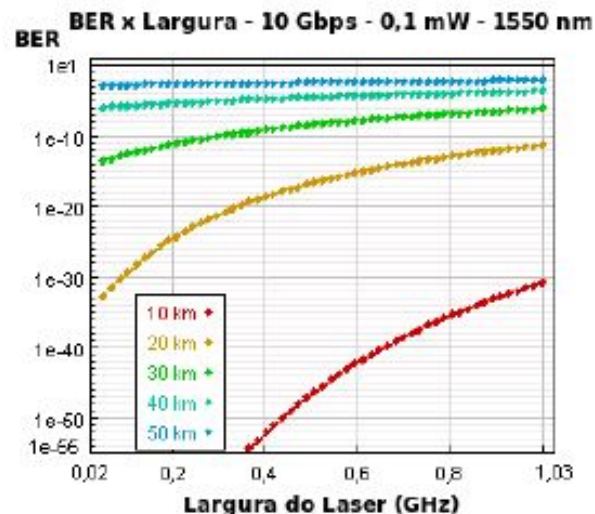
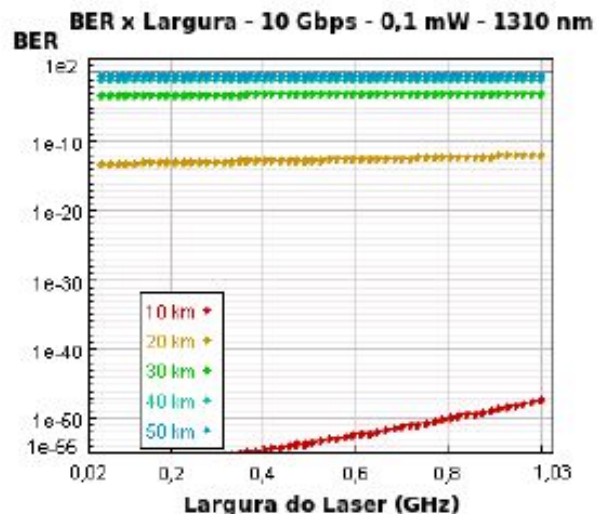


1310 nm

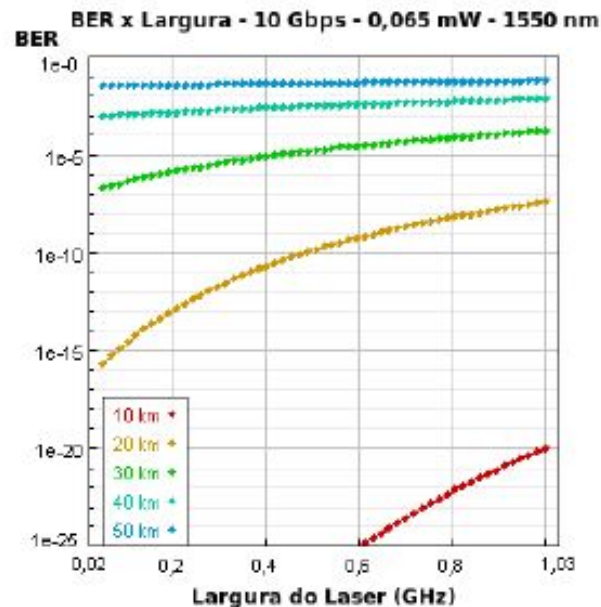
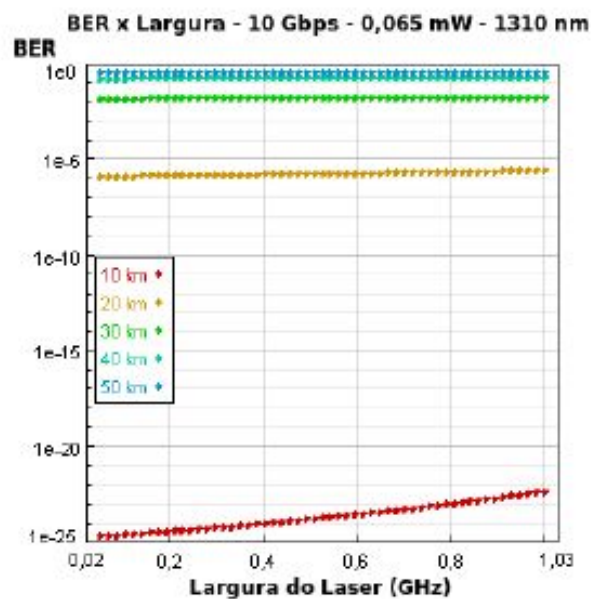
1550 nm



0,1 mW



0,065 mW



1310 nm

1550 nm

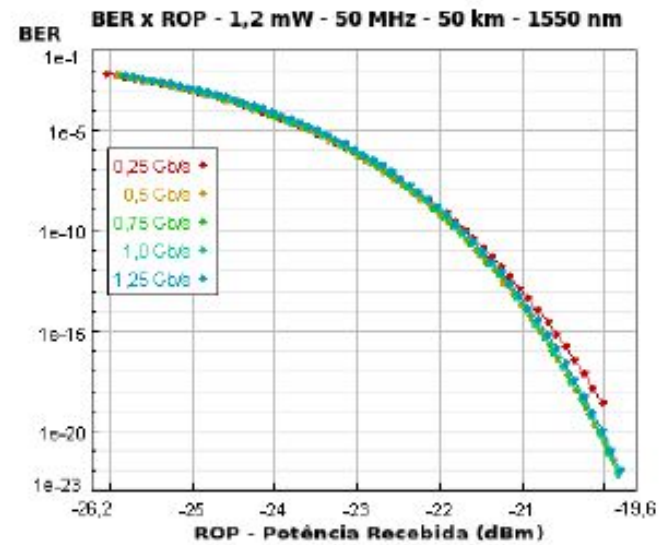
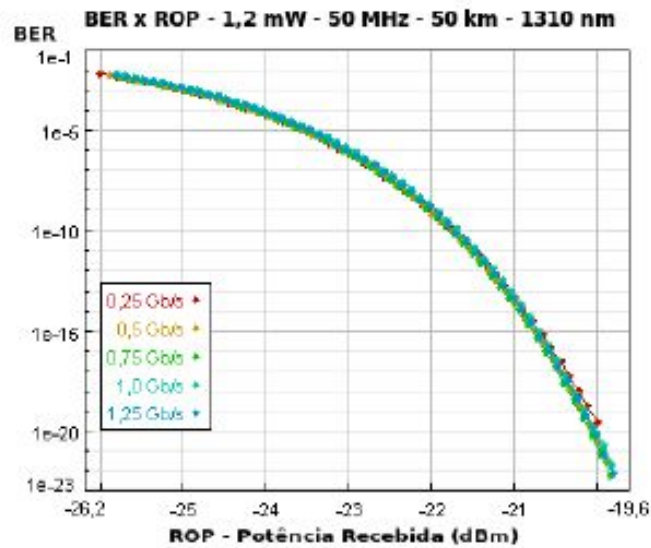
# BER em função da Potência Recebida (ROP) para várias Taxas de Bits

Parâmetros fixos/alterados (**negrito**):

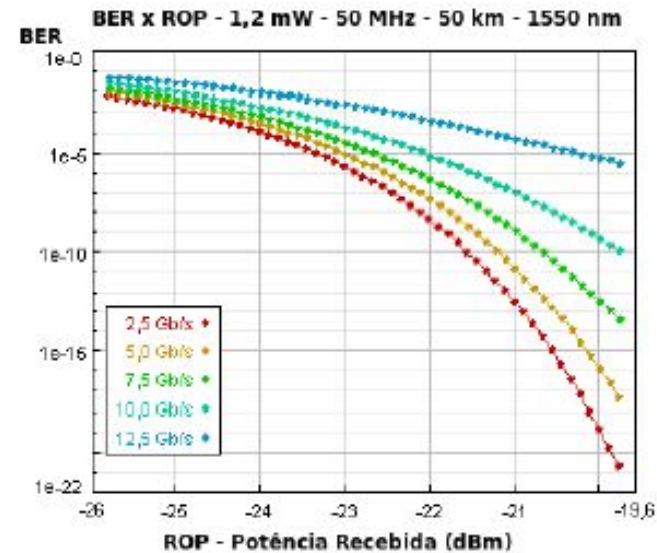
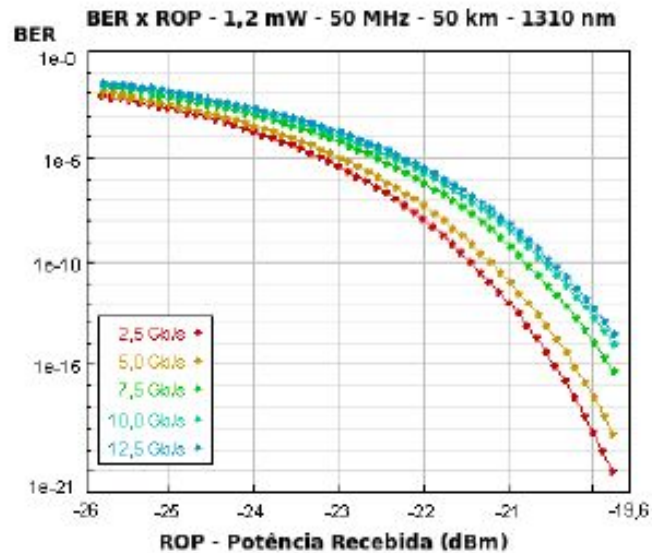
Parâmetros	Valores
<b>Largura do Laser 1310 nm</b>	<b>50 MHz e 1 GHz</b>
<b>Largura do Laser 1550 nm</b>	<b>50 MHz e 1 GHz</b>
Potência Laser	1,2 mW
<b>Taxa de Bit</b>	<b>0,25 até 1,25 Gbps (5 curvas)</b> <b>2,5 até 12,5 Gbps (5 curvas)</b>
Atenuação de Entrada 1310 nm	0 até 6 dBm (55 pontos)
Atenuação de Entrada 1550 nm	6,5 até 12,5 dBm (55 pontos)
Comprimento da Fibra	50 km
Perda por Inserção	1,3 dBm
Atenuação da Fibra 1310nm	0,35 dBm/km
Atenuação da Fibra 1550nm	0,22 dBm/km
Dispersão 1310 nm	0 ps/nm.km
Dispersão 1550 nm	$17,38 \cdot 10^{-6}$ ps/nm.km

- BER diminui com a ROP
- Varia pouco para taxas entre 0,25 e 1,25 Gbps
- BER aumenta; quando aumenta a taxa de 2,5 para 12,5 Gbps
- BER diminui; quando a largura passa de 50 MHz para 1 GHz (0,25 até 1,25 Gbps)
- BER aumenta; para Taxas de Bits de 2,5 até 5 Gbps

0,25 até 1,25 Gbps



2,5 até 12,5 Gbps

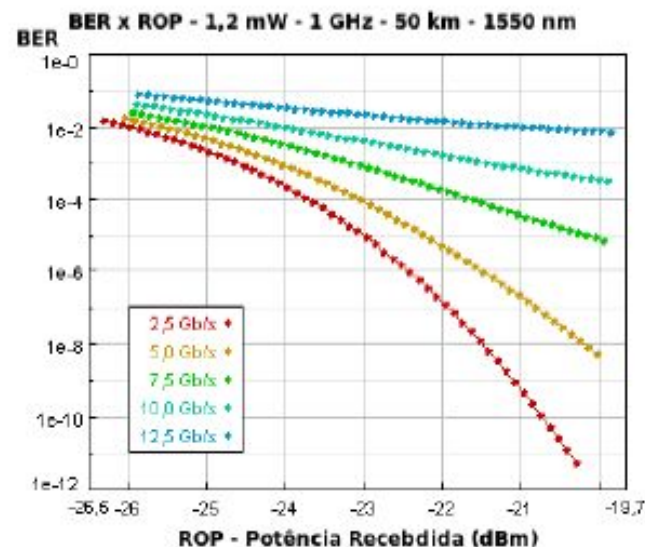
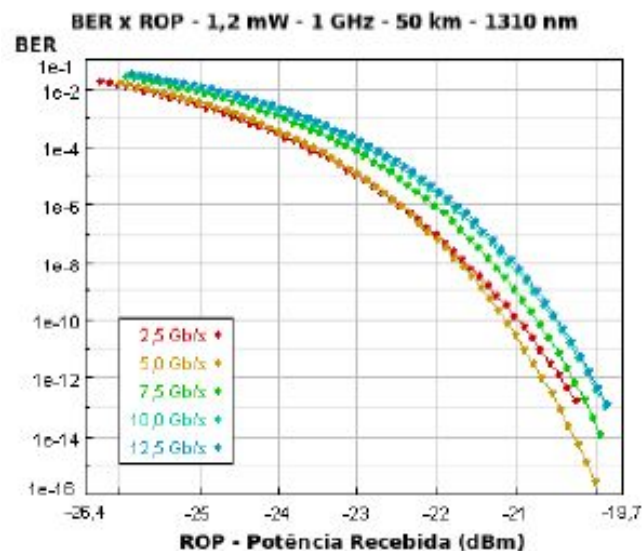
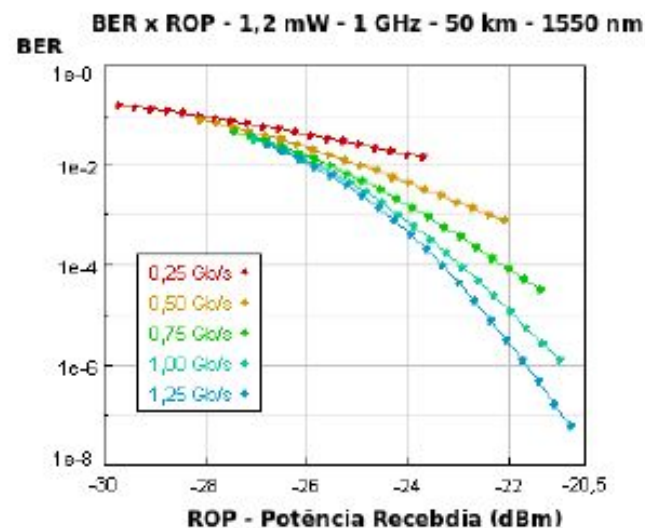
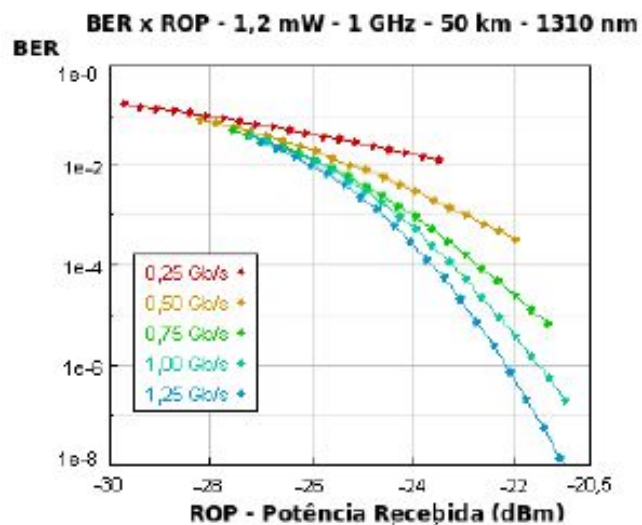


1310 nm

1550 nm

0,25 até 1,25 Gbps

2,5 até 12,5 Gbps

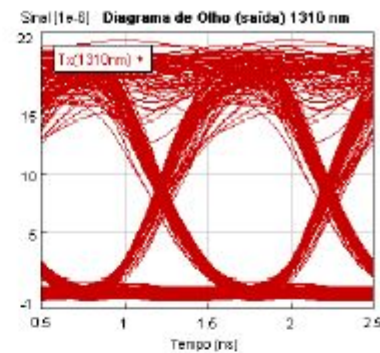
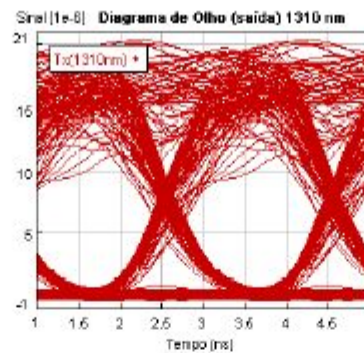
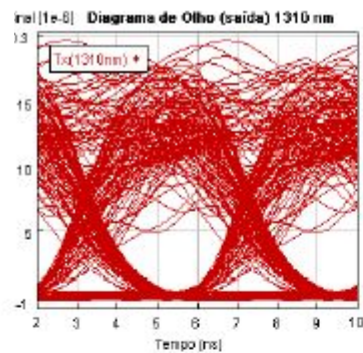


1310 nm

1550 nm

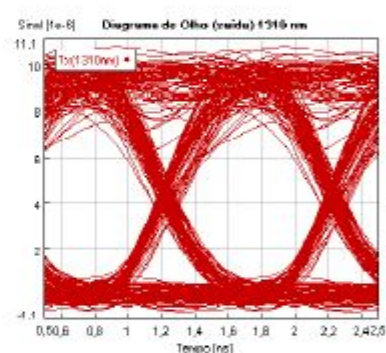
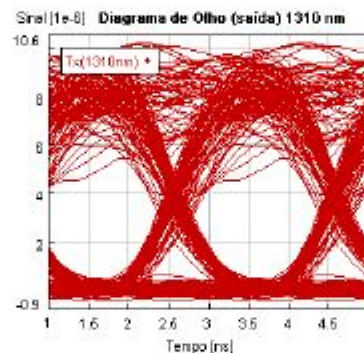
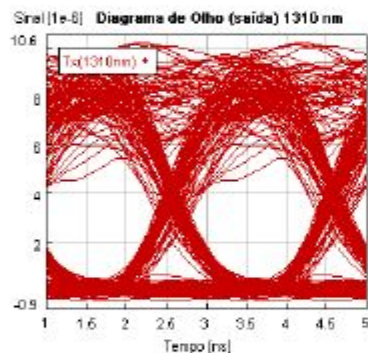


0 dBm

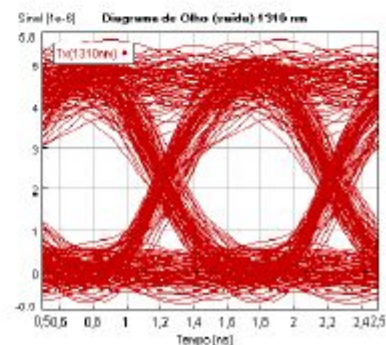
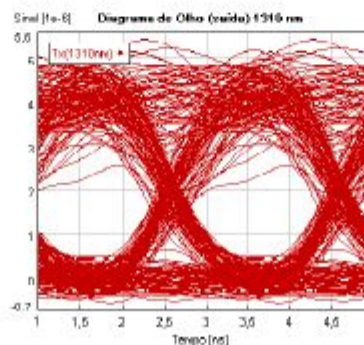
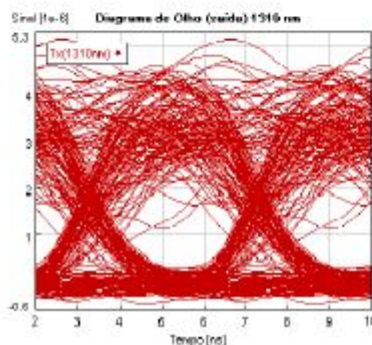


Tx(1310 nm)

3 dBm



6 dBm



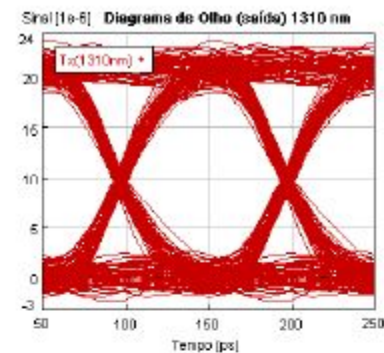
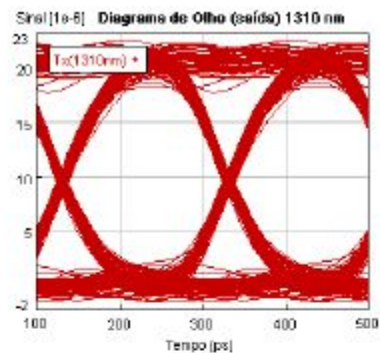
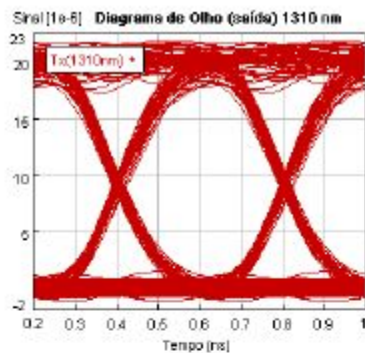
0,25 Gbps

0,5 Gbps

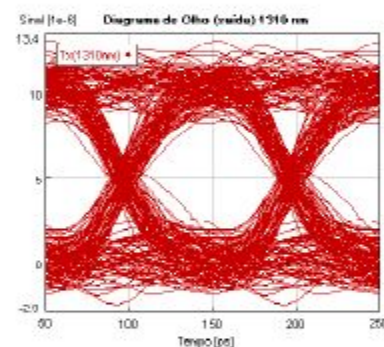
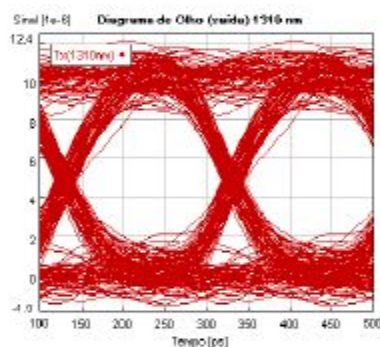
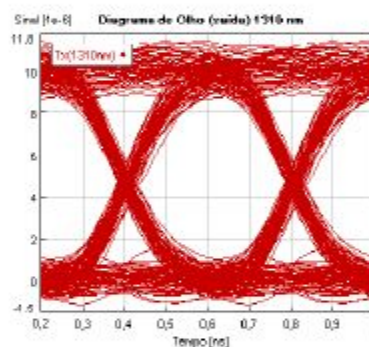
1 Gbps

**Tx(1310 nm)**

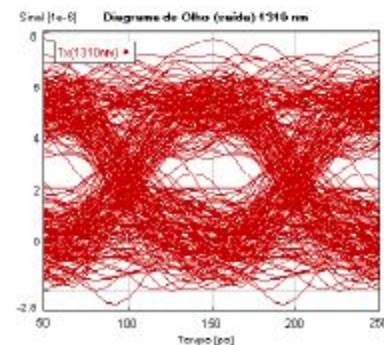
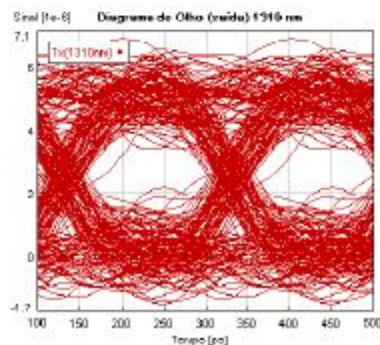
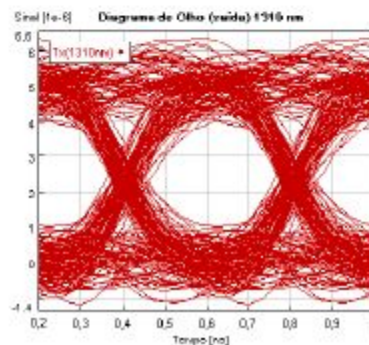
**0 dBm**



**3 dBm**



**6 dBm**



**2,5 Gbps**

**5 Gbps**

**10 Gbps**

# BER em função da Taxa de Bits para várias Larguras

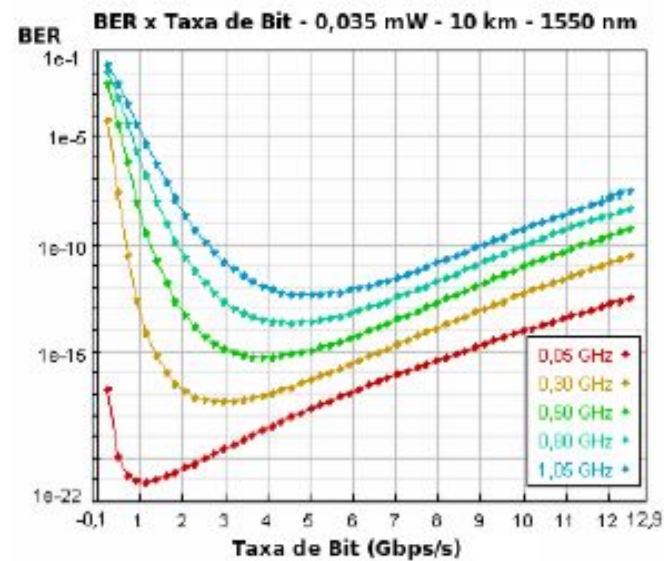
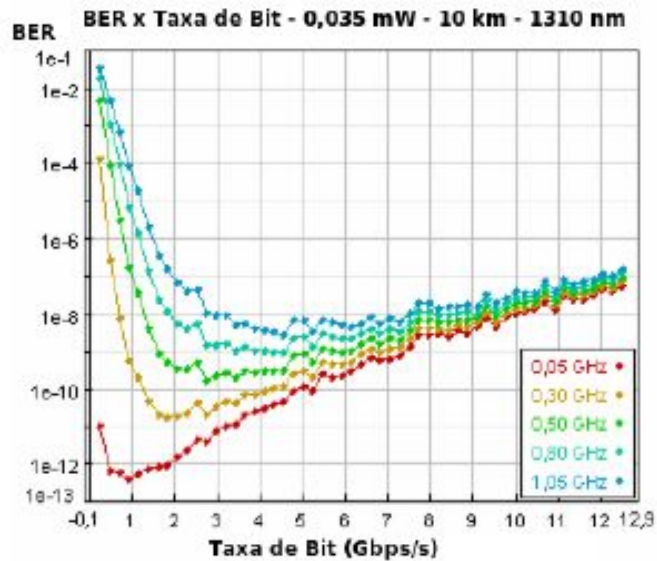
Parâmetros fixos/alterados (**negrito**):

Parâmetros	Valores
<b>Largura do Laser 1310 nm</b>	<b>50 MHz até 1,05 GHz</b>
<b>Largura do Laser 1550 nm</b>	<b>50 MHz até 1,05 GHz</b>
<b>Potência Laser</b>	<b>0,035 mW para 10 km e 0,25 mW para 50 km</b>
<b>Taxa de Bit</b>	<b>0,25 Gbps até 12,5 Gbps (5 curvas)</b>
Atenuação de Entrada 1310 nm	0 dBm
Atenuação de Entrada 1550 nm	0 dBm
<b>Comprimento da Fibra</b>	<b>10 e 50 km</b>
Perda por Inserção	1,3 dBm
Atenuação da Fibra 1310nm	0,35 dBm/km
Atenuação da Fibra 1550nm	0,22 dBm/km
Dispersão 1310 nm	0 ps/nm.km
Dispersão 1550 nm	$17,38 \cdot 10^{-6}$ ps/nm.km

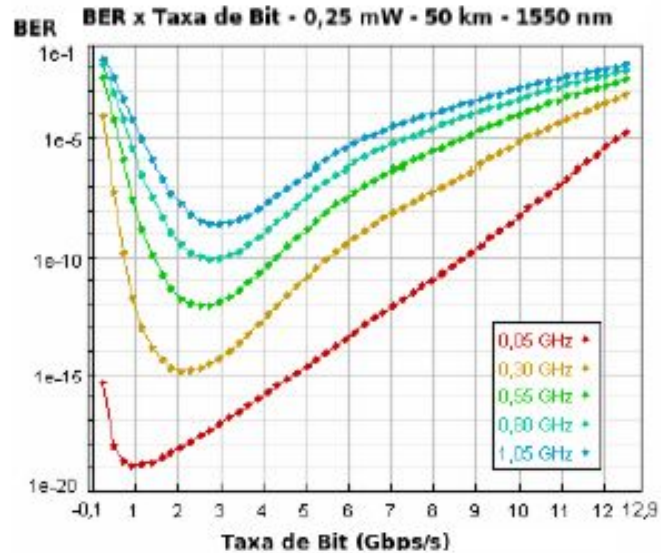
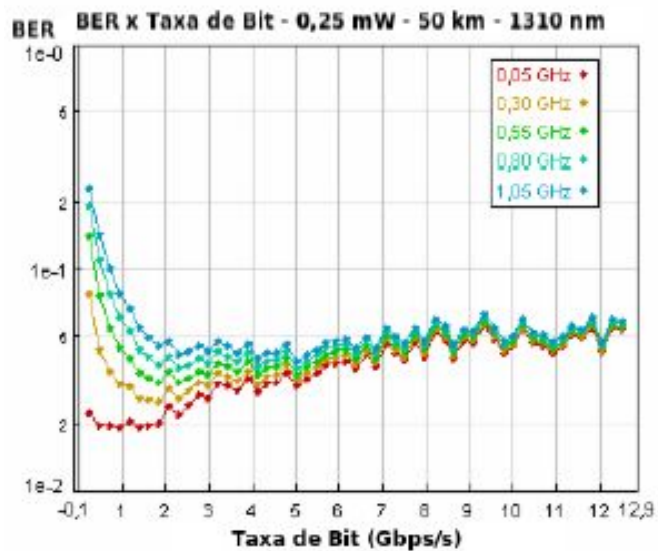
- BER diminui com a Taxa de Bits
- Valor mínimo (1 – 5 Gbps) para a BER em função da Largura do Laser
- BER aumenta com a Taxa de Bits



0,035 mW



0,25 mW

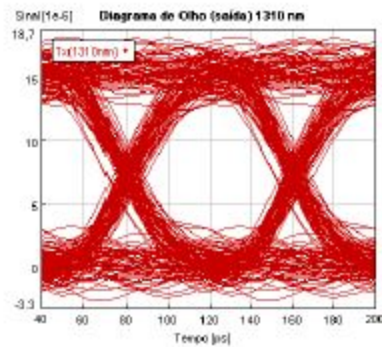
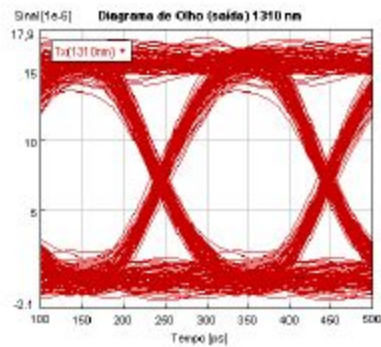
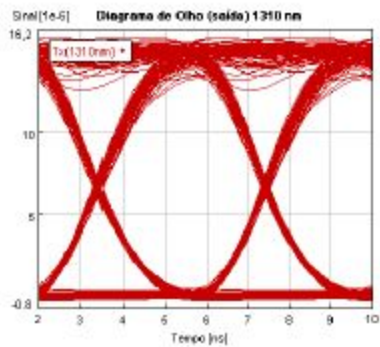


1310 nm

1550 nm

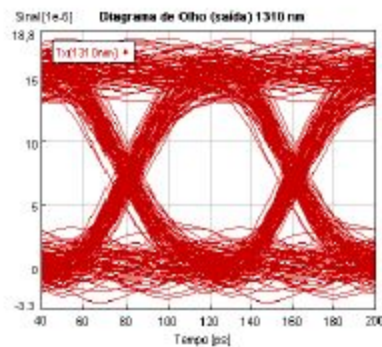
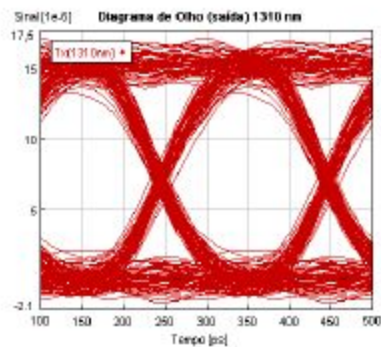
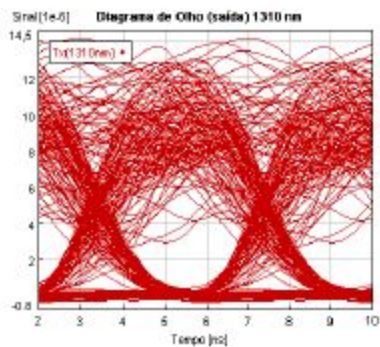


0,05 GHz

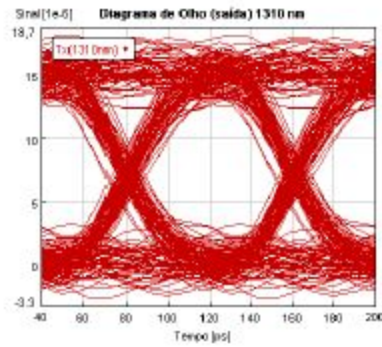
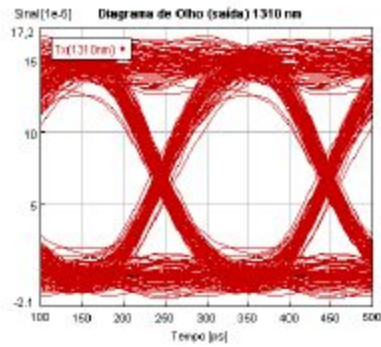
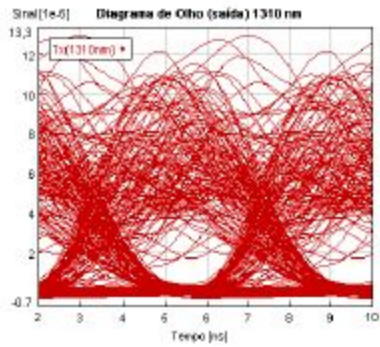


Tx(1310 nm)  
10 km

0,55 GHz



1,05 GHz

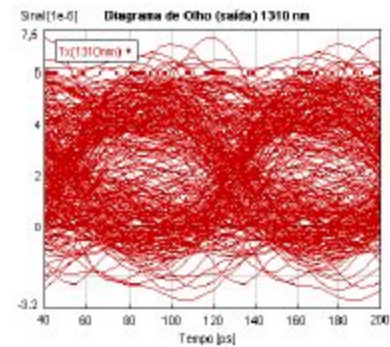
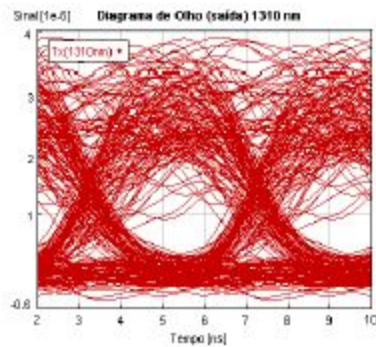
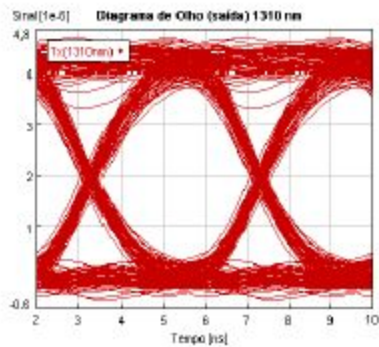


0,25 Gbps

5 Gbps

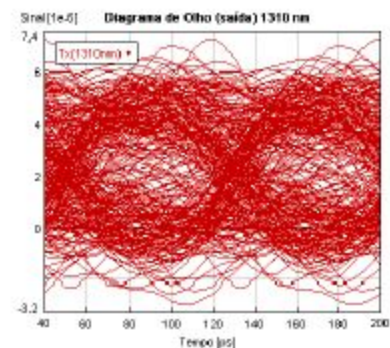
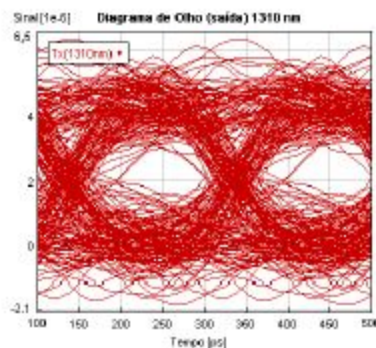
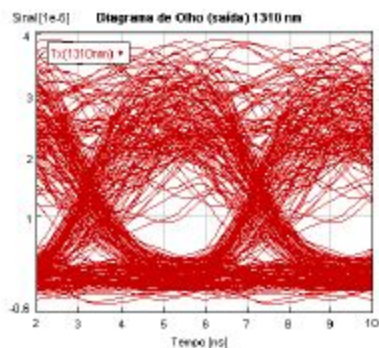
12,5 Gbps

0,05 GHz

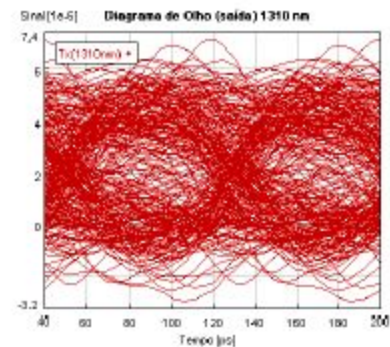
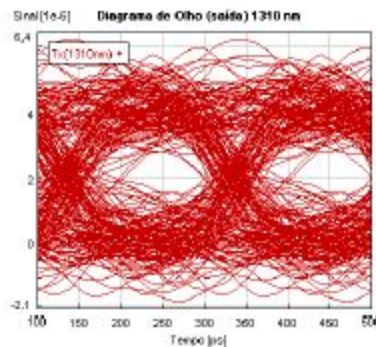
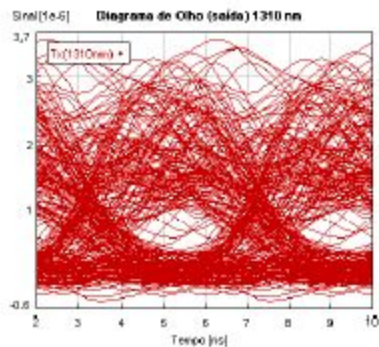


**Tx(1310 nm)**  
**50 km**

0,55 GHz



1,05 GHz



**0,25 Gbps**

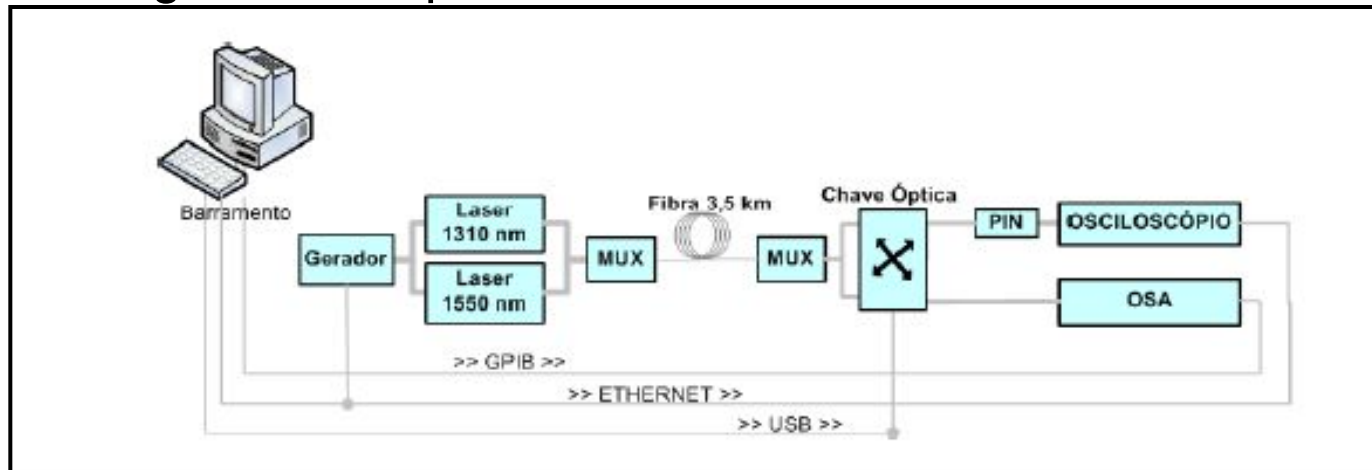
**5 Gbps**

**12,5 Gbps**

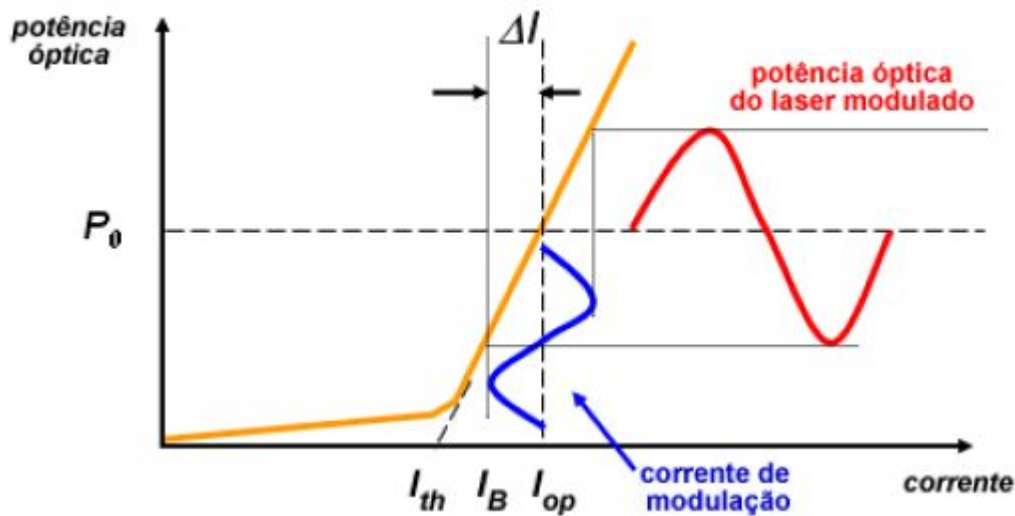


# Diagrama da Montagem Experimental.

## ■ Diagrama e Experimento



# Modulação Direta da Corrente dos Lasers.



$$P(t) = P_0[1 + m \sin(\omega t)]$$

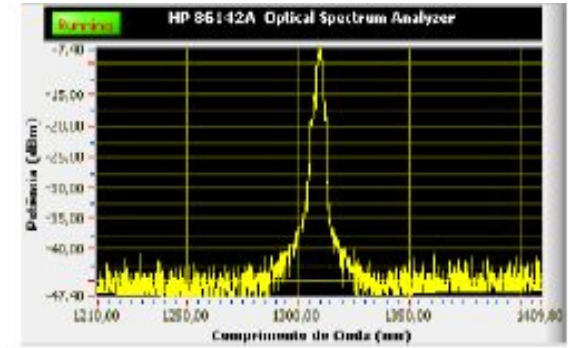
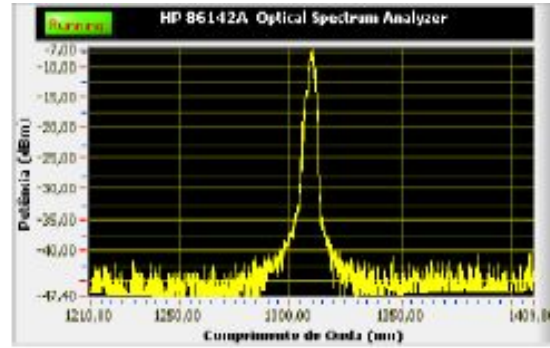
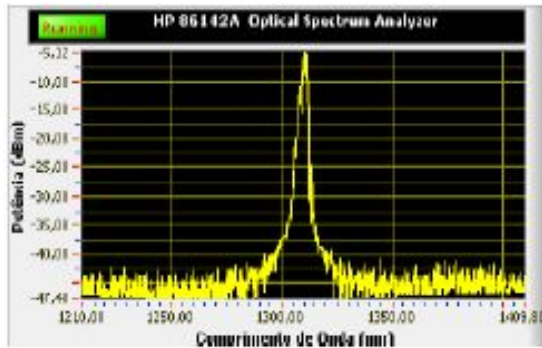
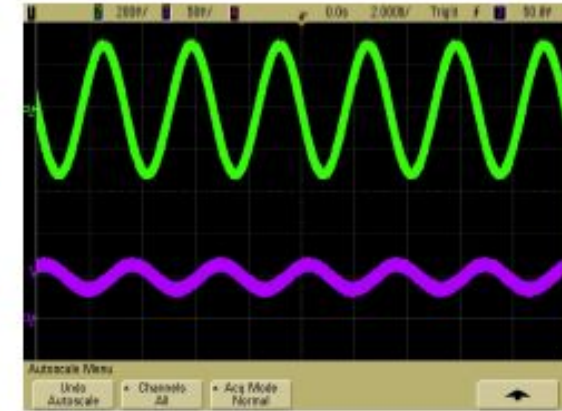
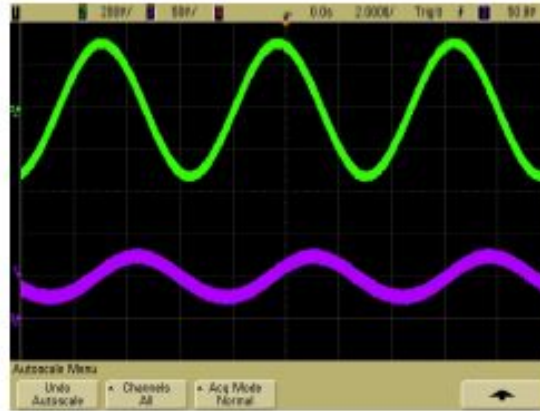
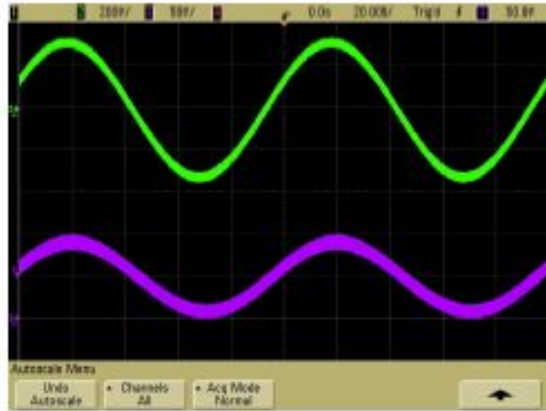
$$m = \frac{\Delta I}{I_B}$$

$$I_B = I_{op} - I_{th}$$

- Determinação das Curvas L-I e Espectros dos Lasers
- Análise das Formas de Onda e Espectros (sinais entrada/saída)
- Determinação das Curvas de Resposta em Freqüência

# Caracterização Local - Modulação Direta da Corrente dos Lasers.

1310 nm



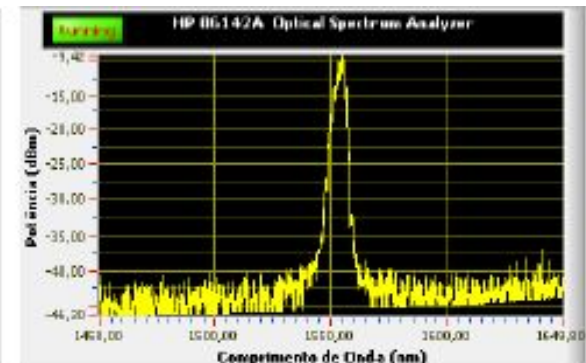
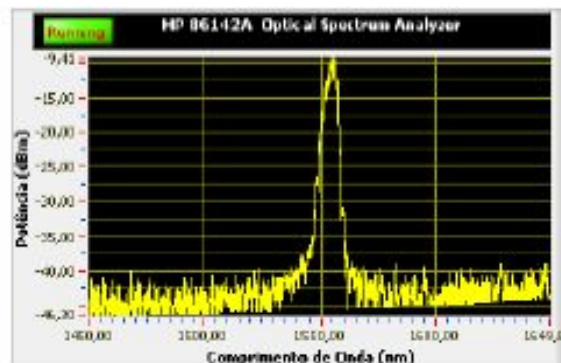
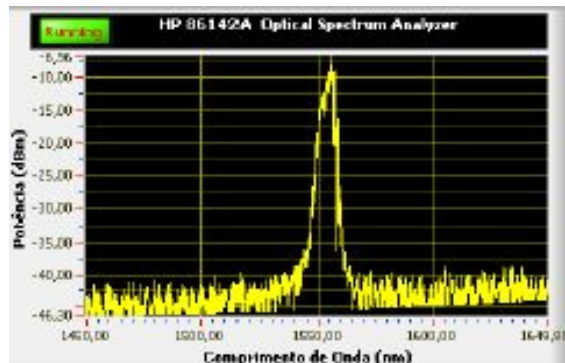
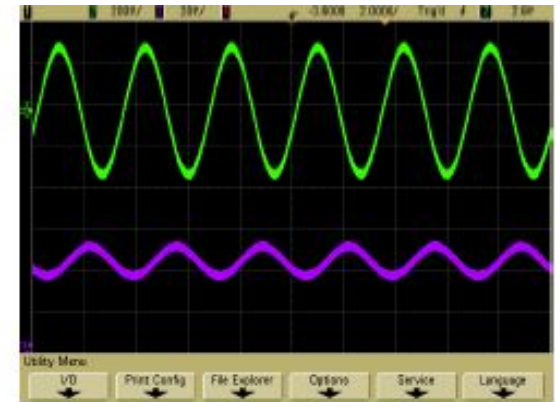
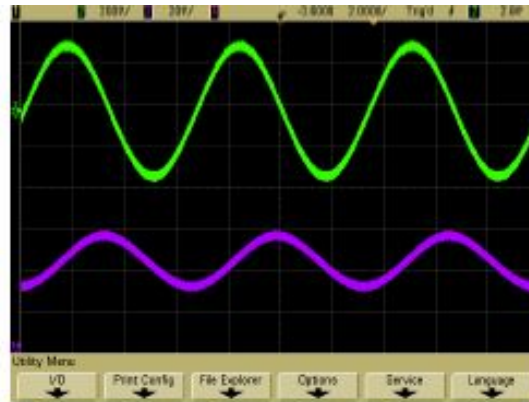
10 kHz

150 kHz

300 kHz

# Caracterização Local - Modulação Direta da Corrente dos Lasers.

1550 nm



10 kHz

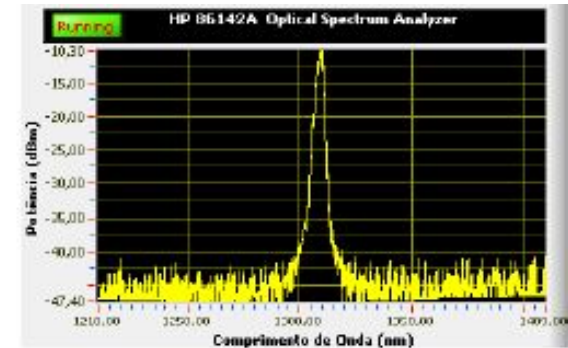
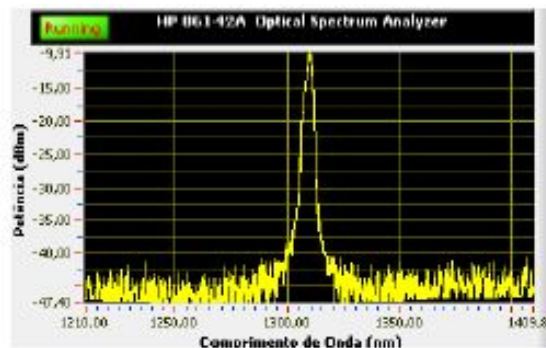
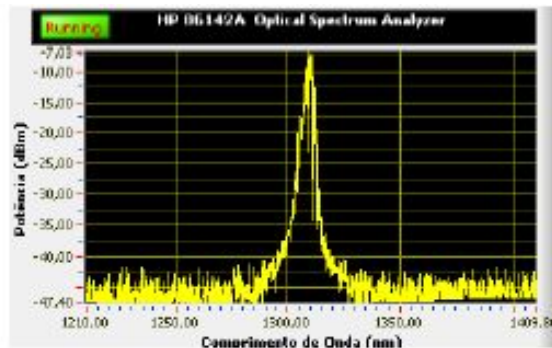
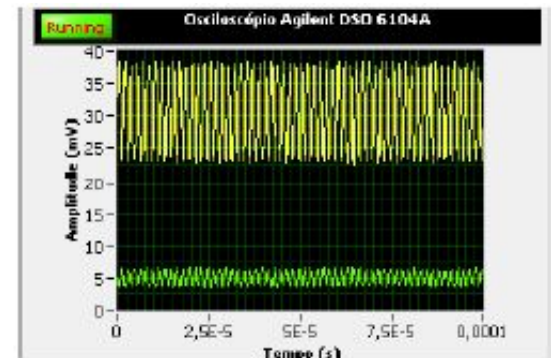
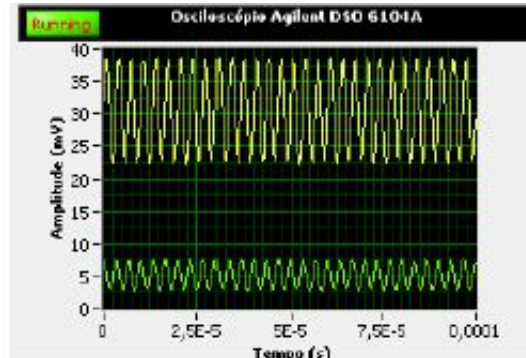
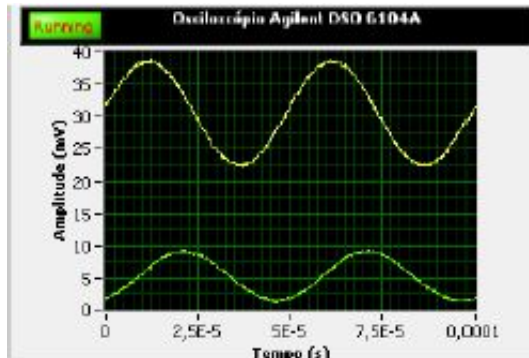
150 kHz

300 kHz



# Caracterização Remota - Modulação Direta da Corrente dos Lasers.

1310 nm



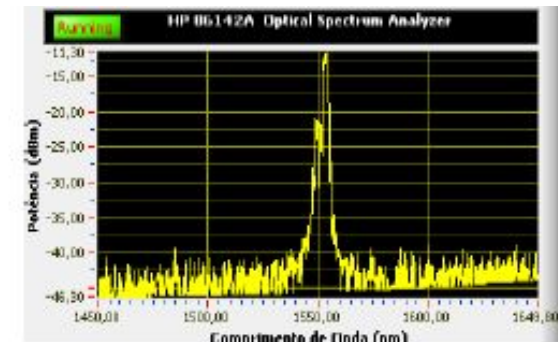
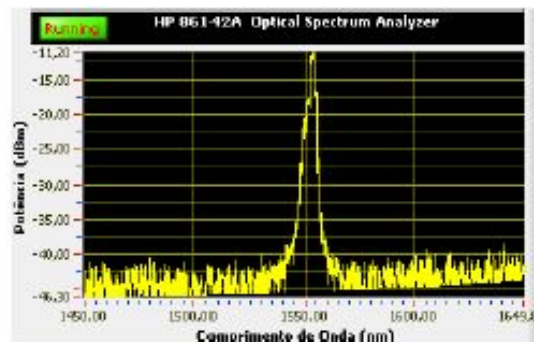
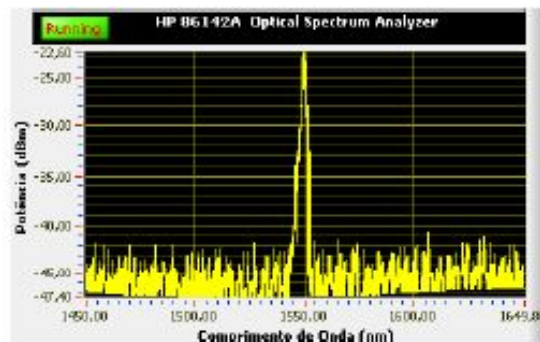
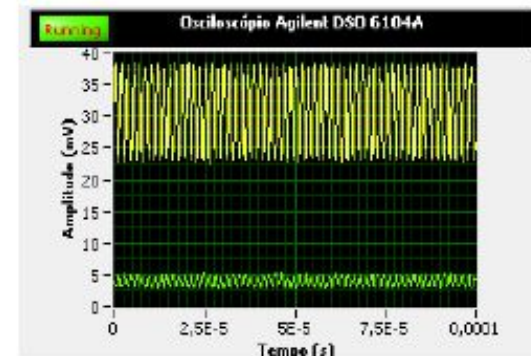
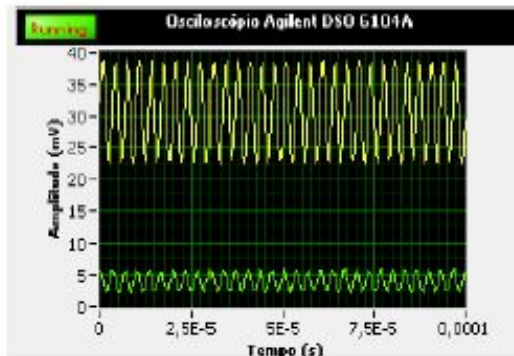
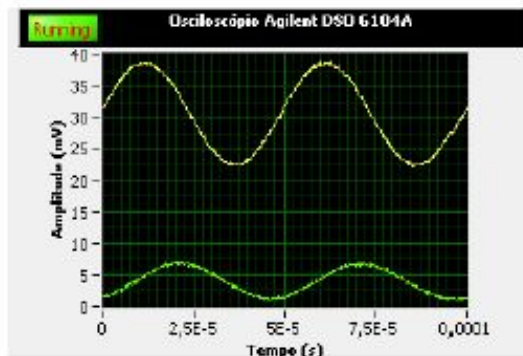
10 kHz

150 kHz

300 kHz

# Caracterização Remota - Modulação Direta da Corrente dos Lasers.

1550 nm



10 kHz

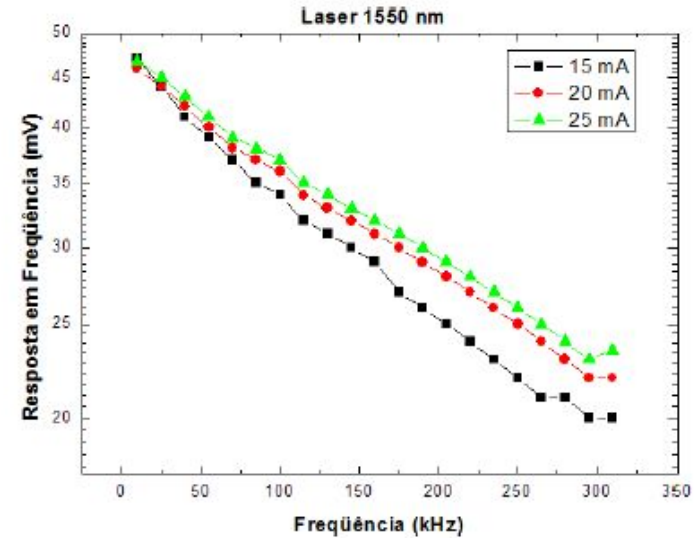
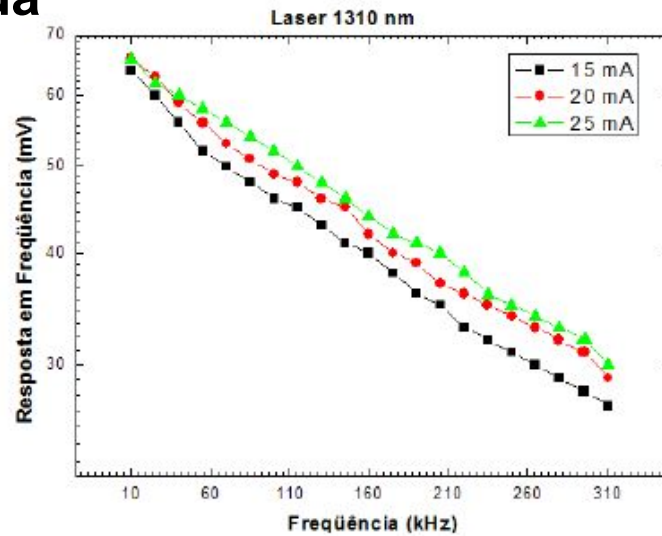
150 kHz

300 kHz

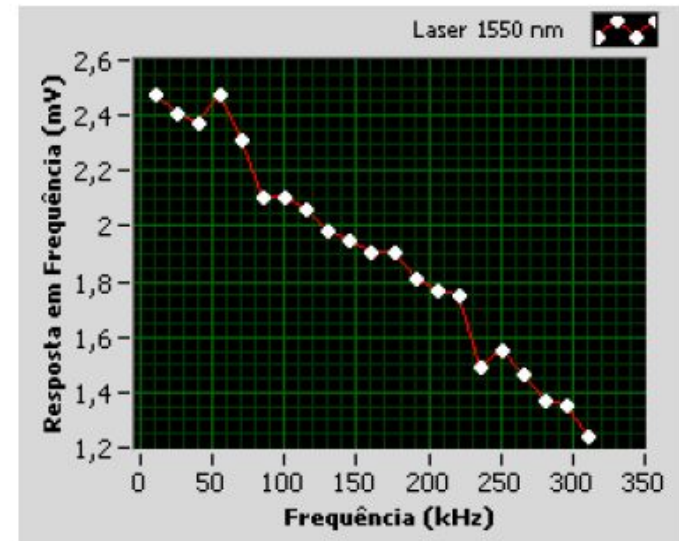
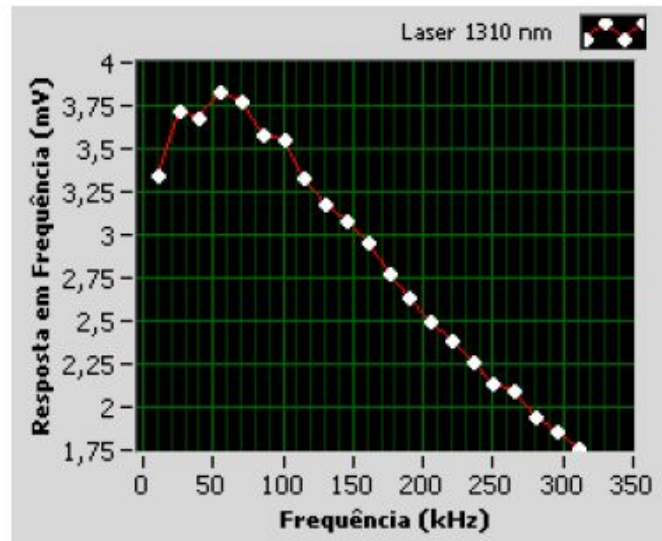


# Curvas de Resposta em Frequência

## ■ Entrada



## ■ Saída



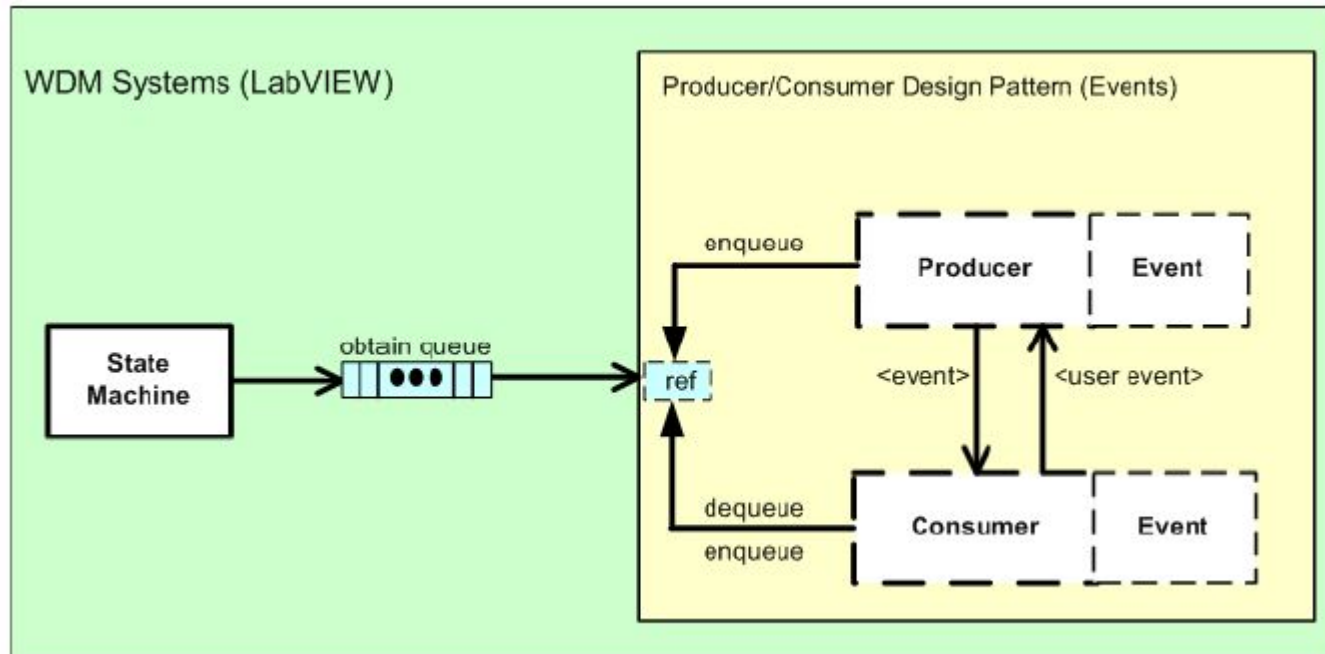
# Instrumentação Visual.

**Uso de princípios básicos de boas práticas de programação:**

- Legível (*Readable*)
- Escalável (*Scalable*)
- Mantenível (*Maintanable*)

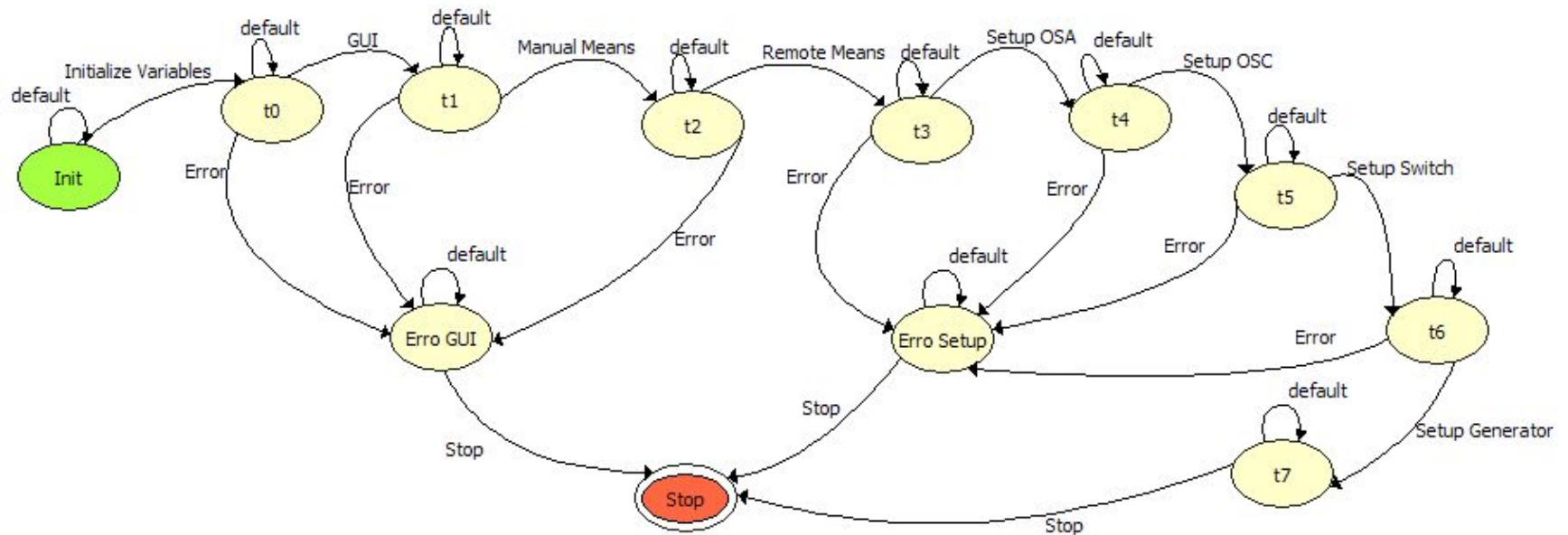
# Instrumentação Virtual.

- Arquitetura do Sistema WDM.



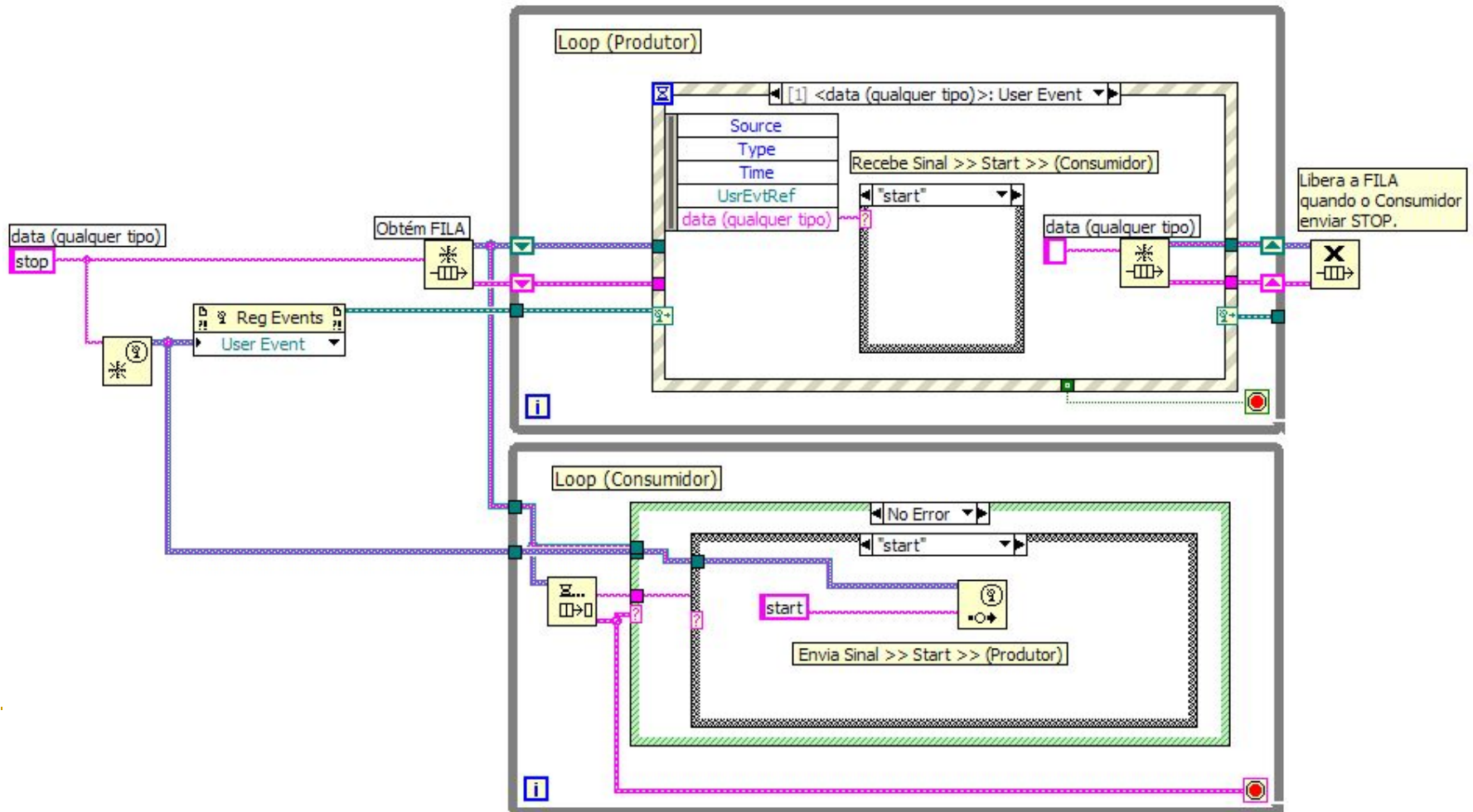
# Instrumentação Virtual – Máquina de Estados.

## ■ Máquina de Estados



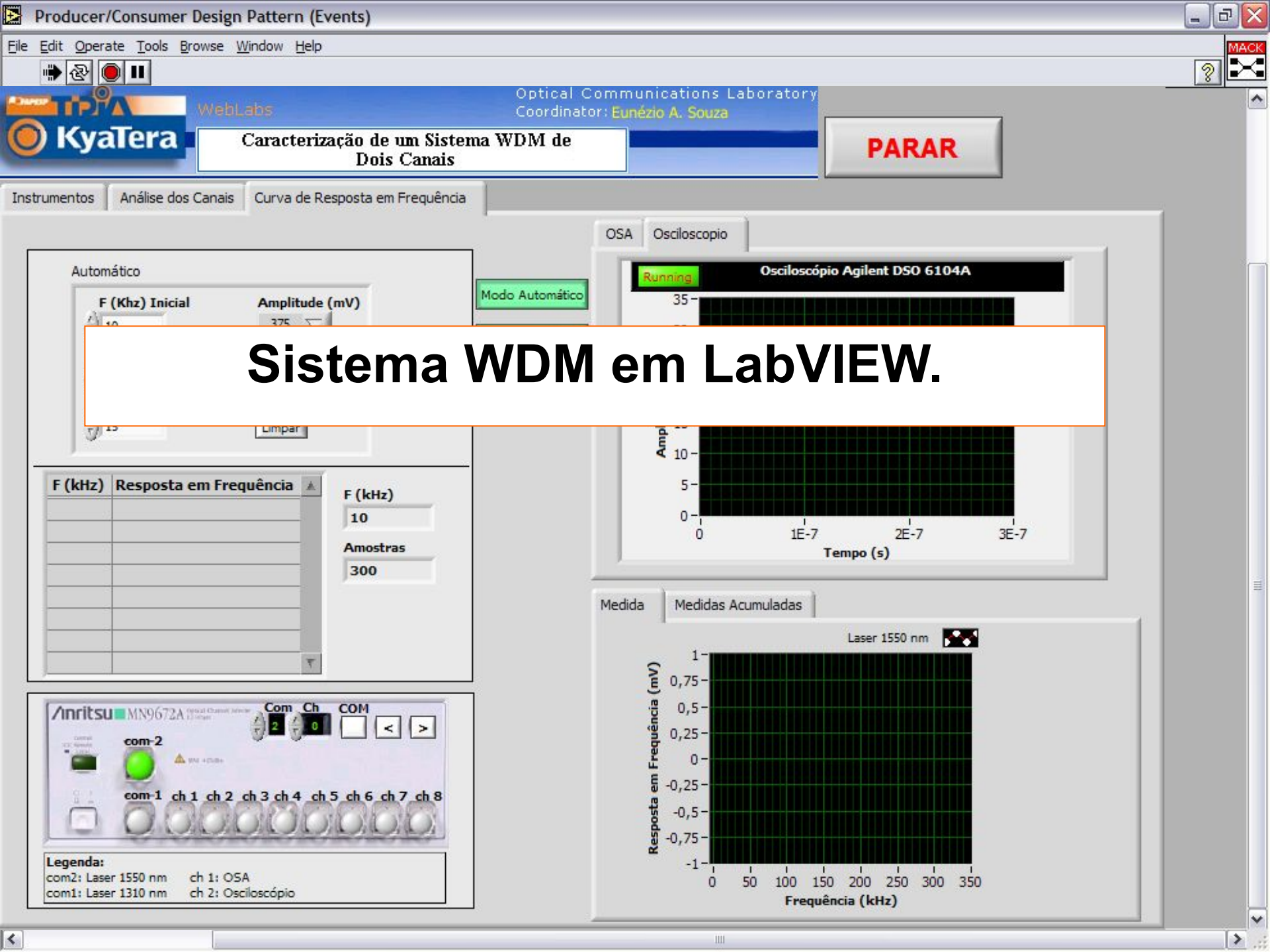
# Instrumentação Virtual – *Producer Consumer* Design Patter.

## ■ Produtor x Consumidor.









# Sistema WDM em LabVIEW.

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# Conclusões e Trabalhos Futuros.

- Desenvolvimento do Módulo WebLab (MOODLE).
  - Análise via simulações (VPI) para os várias parâmetros empregos em um sistema WDM.
  - Desenvolvimento do DDS para simulações via MOODLE.
  - Uso de Padrões de Projeto (*State Machine Diagram e Producer/Consumer - Events*).
  - Limitações quanto as opções de equipamentos.
  - Implementação Futura do Sistema WDM para outros tipos de equipamentos.
-