

All-Optical Modulation of Microring Resonators for Photonic Neural Networks

Zalan Nemeth - 23 May 2025

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Motivation

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- Electronic computing limitations

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- Ultra-high spatial density

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- Massive WDM-enabled parallelism

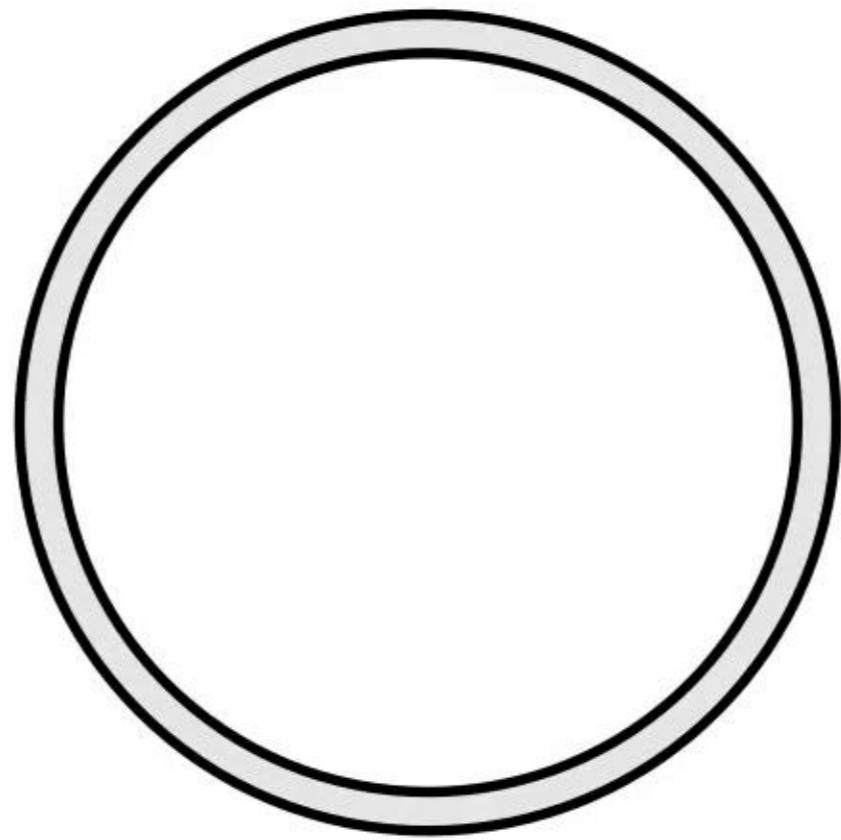
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- Low-loss, low-energy operation

Motivation

- Electronic computing limitations
- Ultra-high spatial density
- Massive WDM-enabled parallelism
- Low-loss, low-energy operation
- Well-suited for applications requiring lower bit precision

Microring

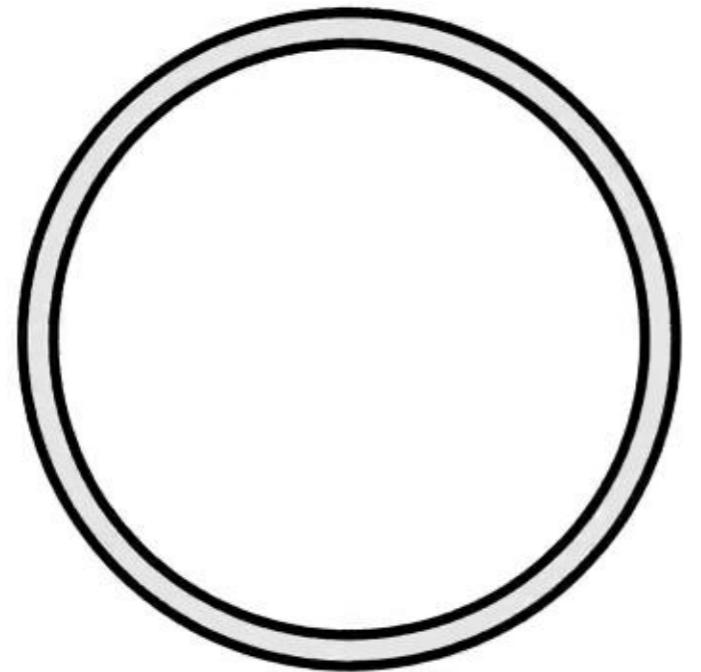


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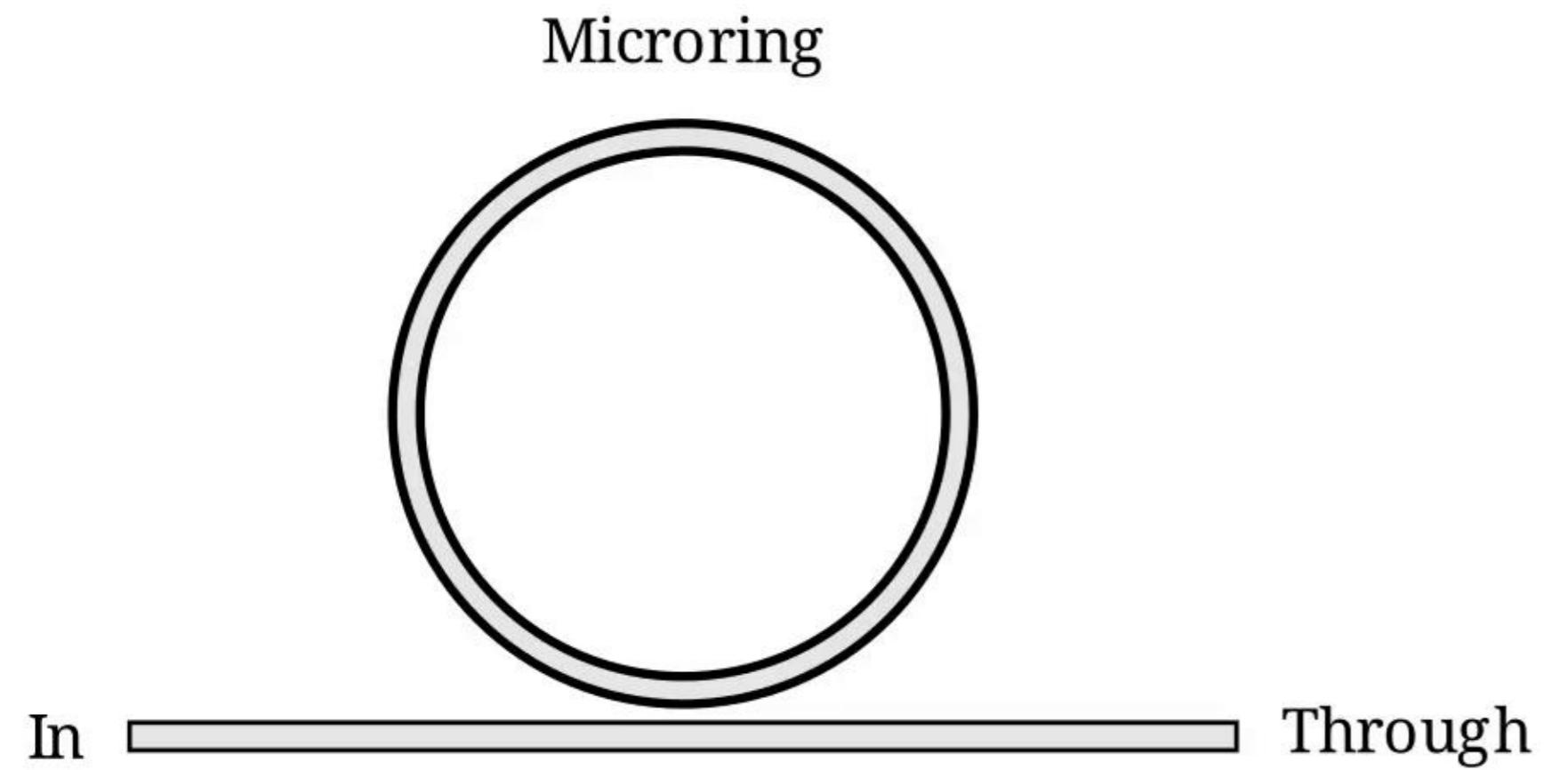


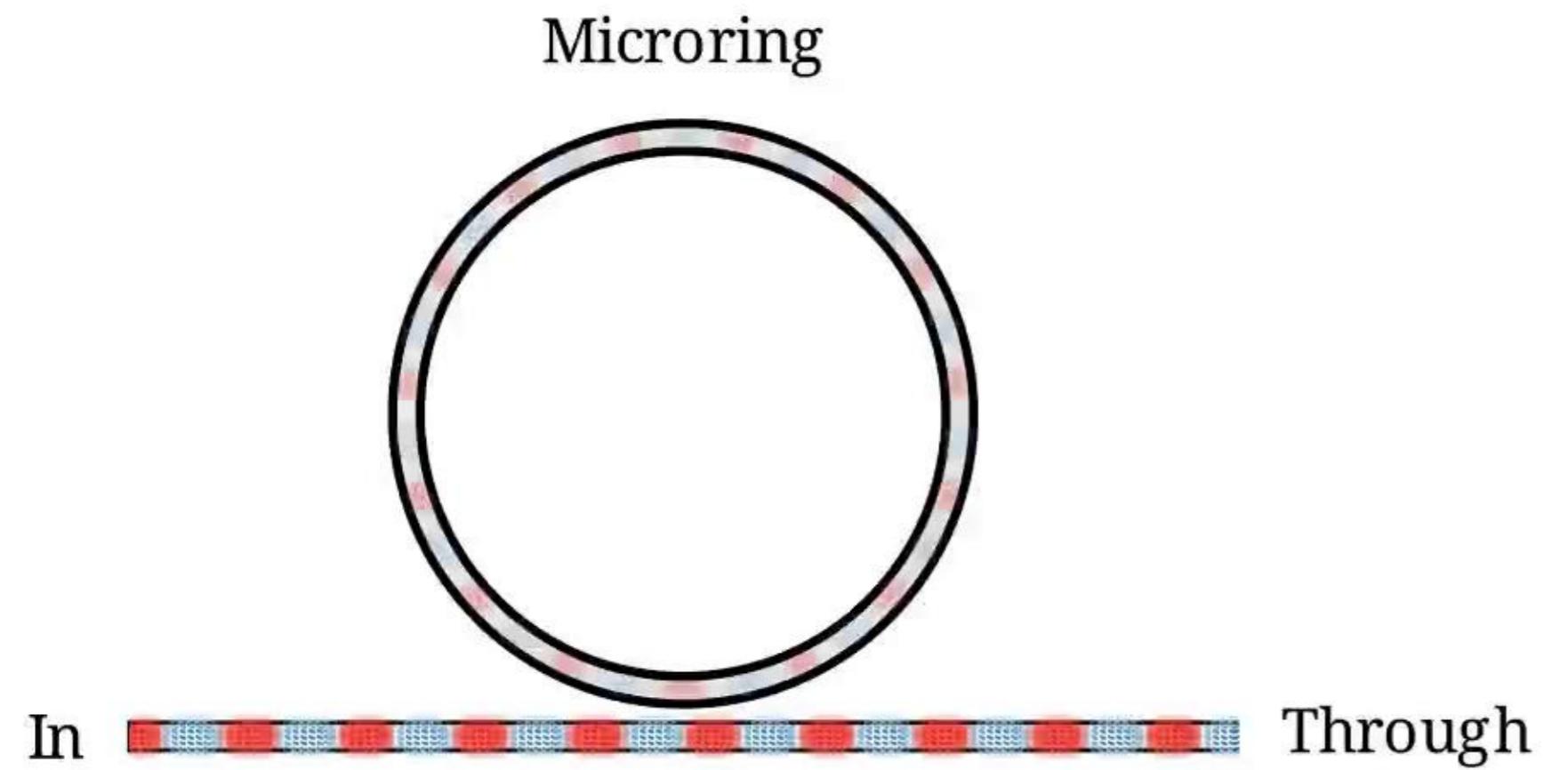
Through

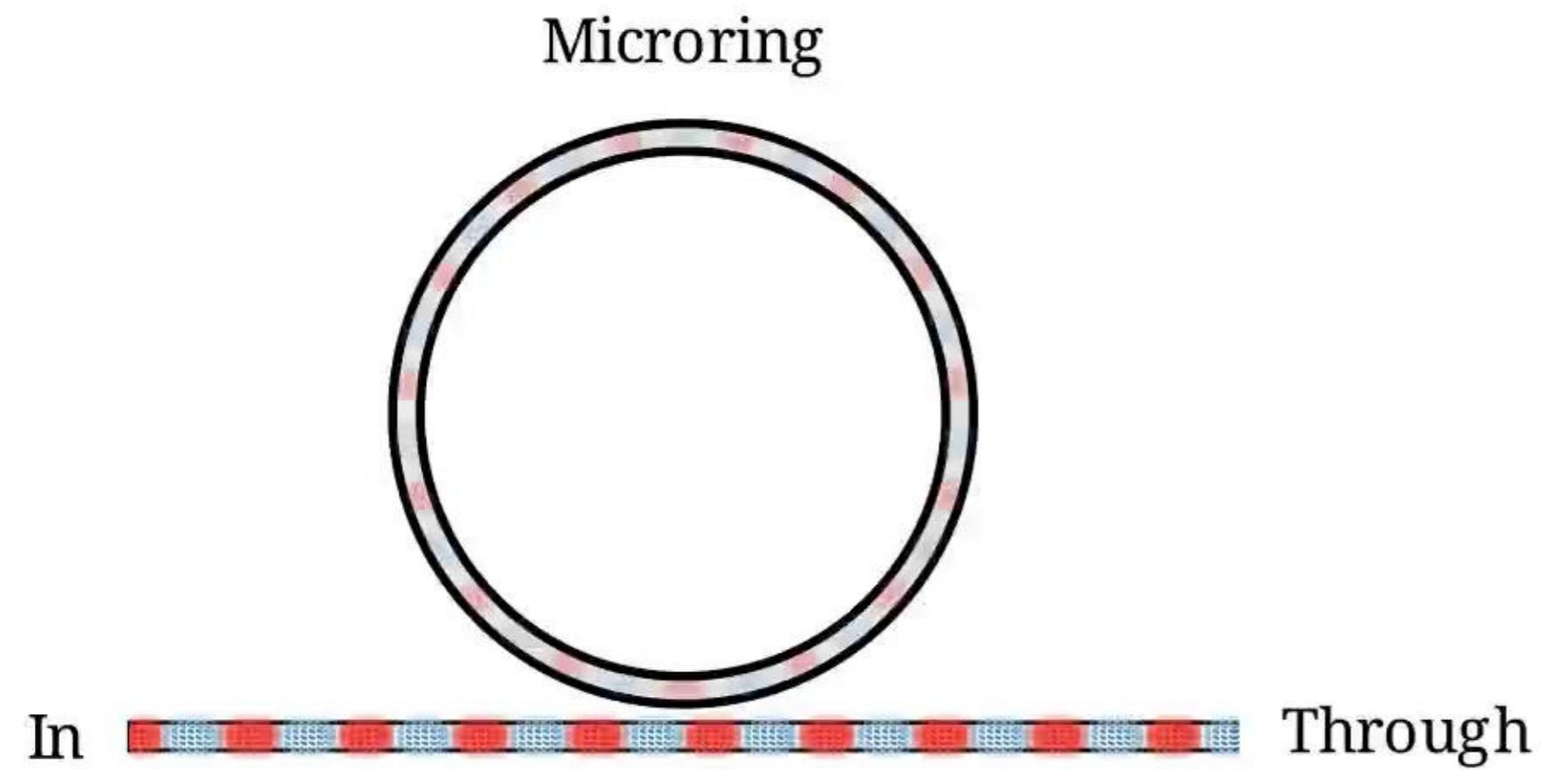
Microring

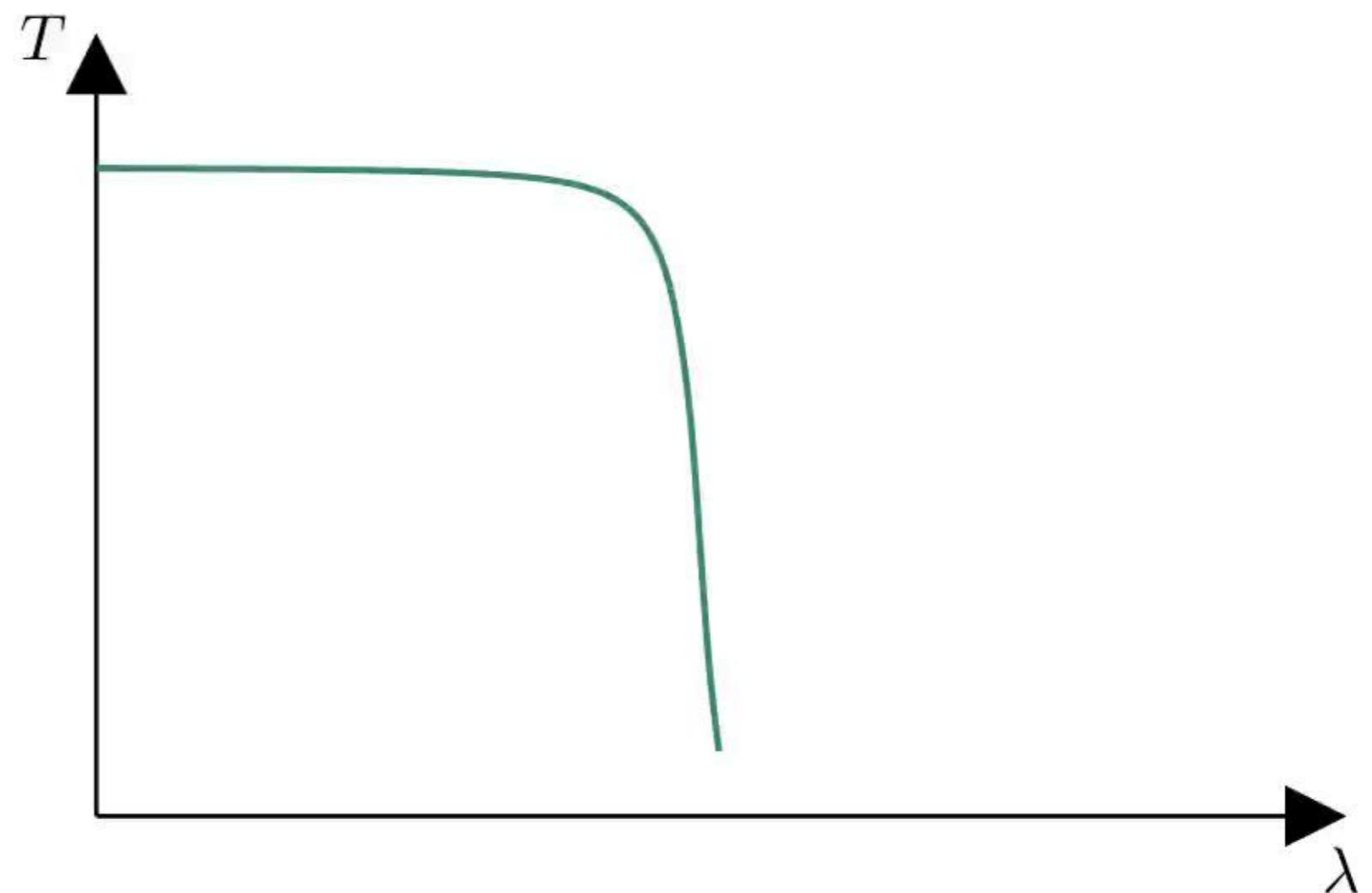
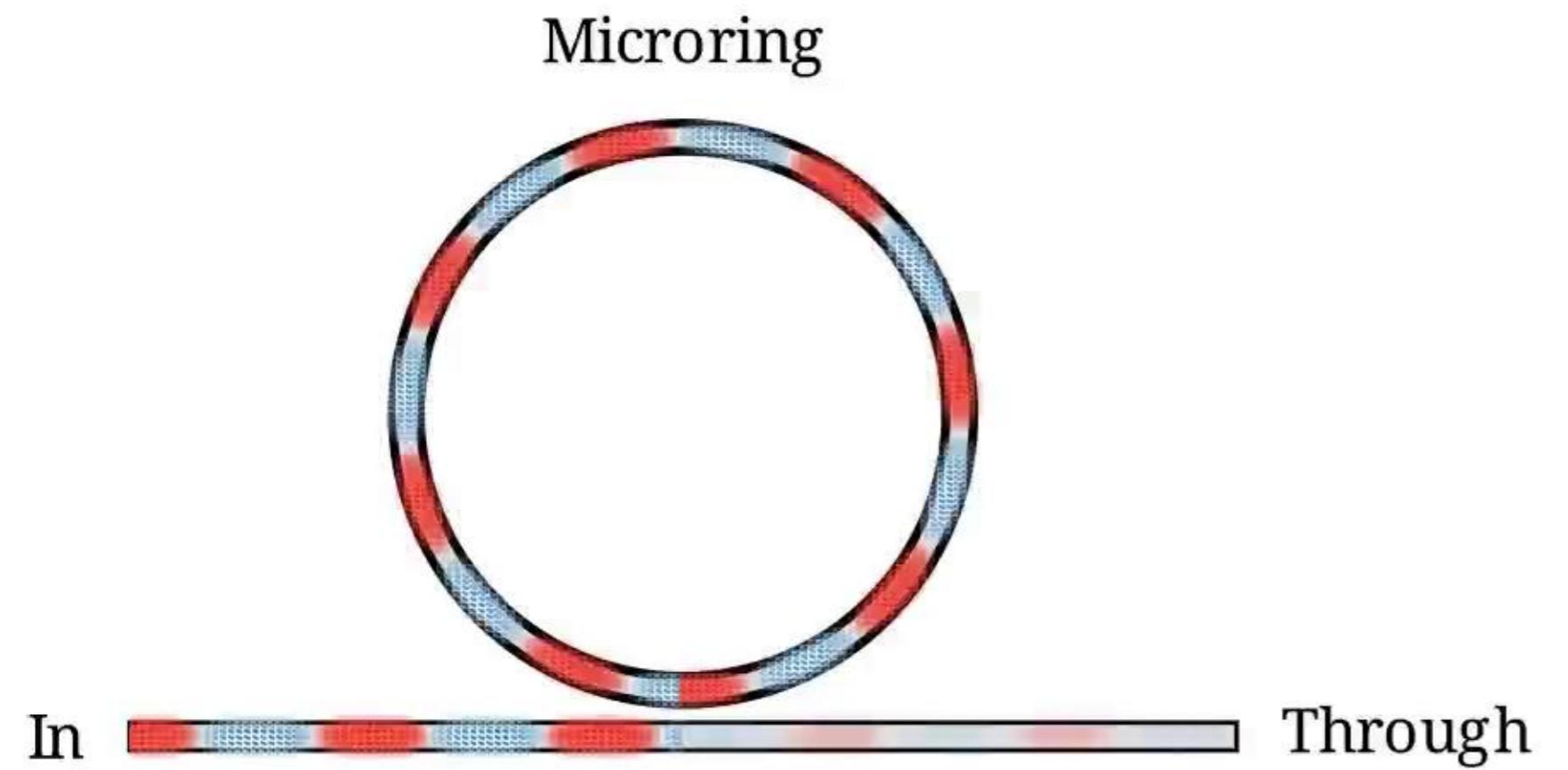


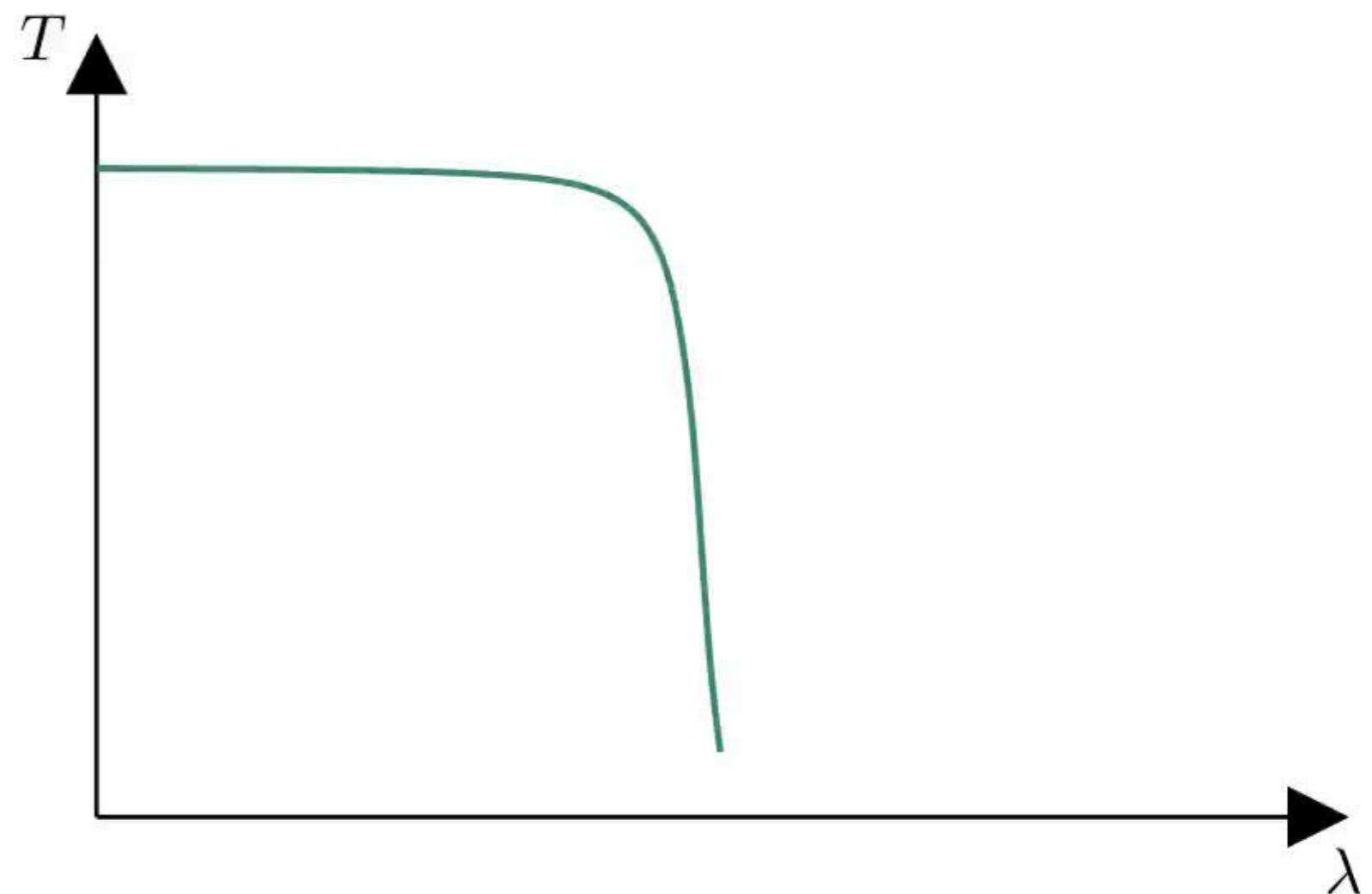
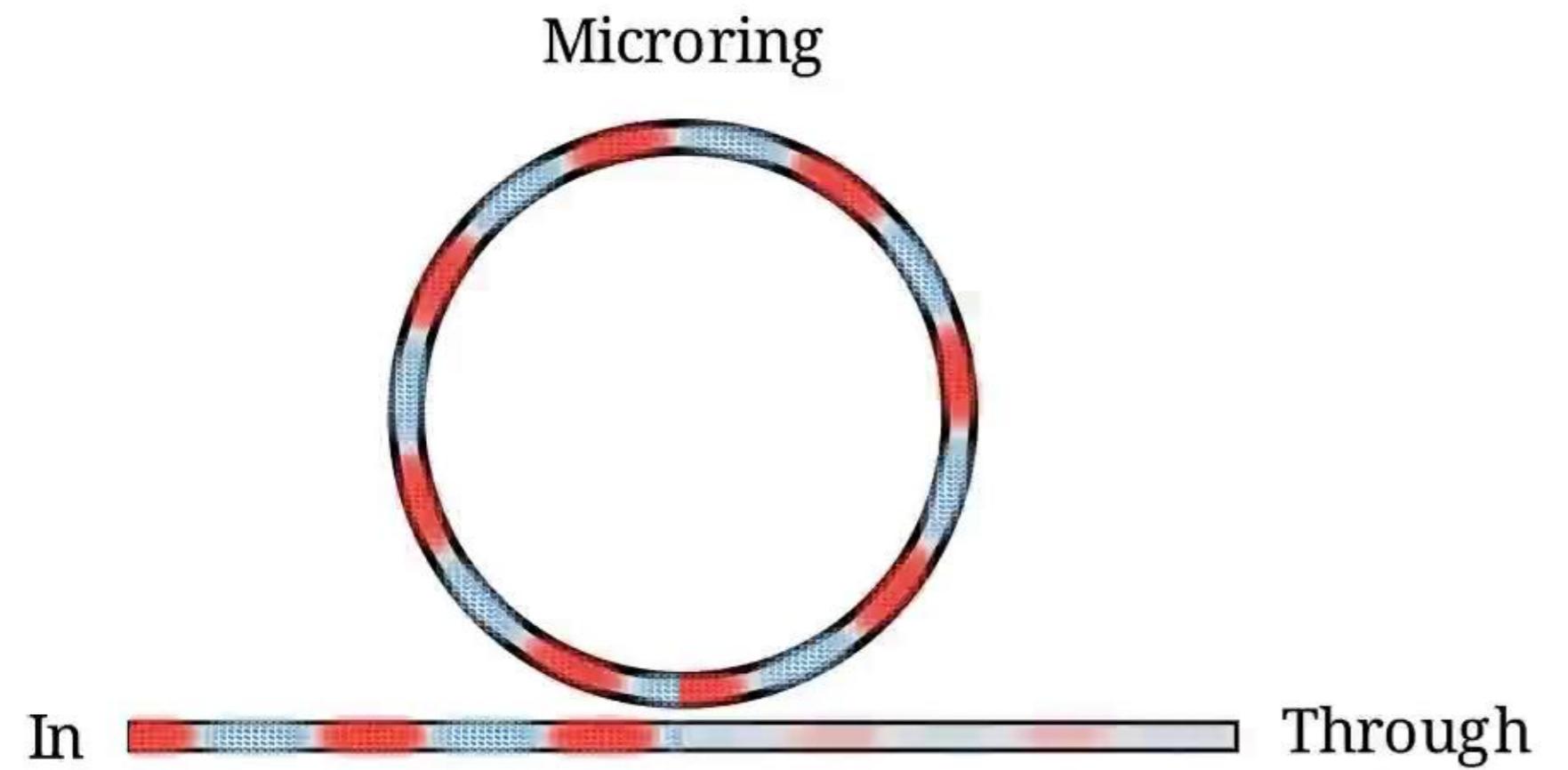
In ━━ Through

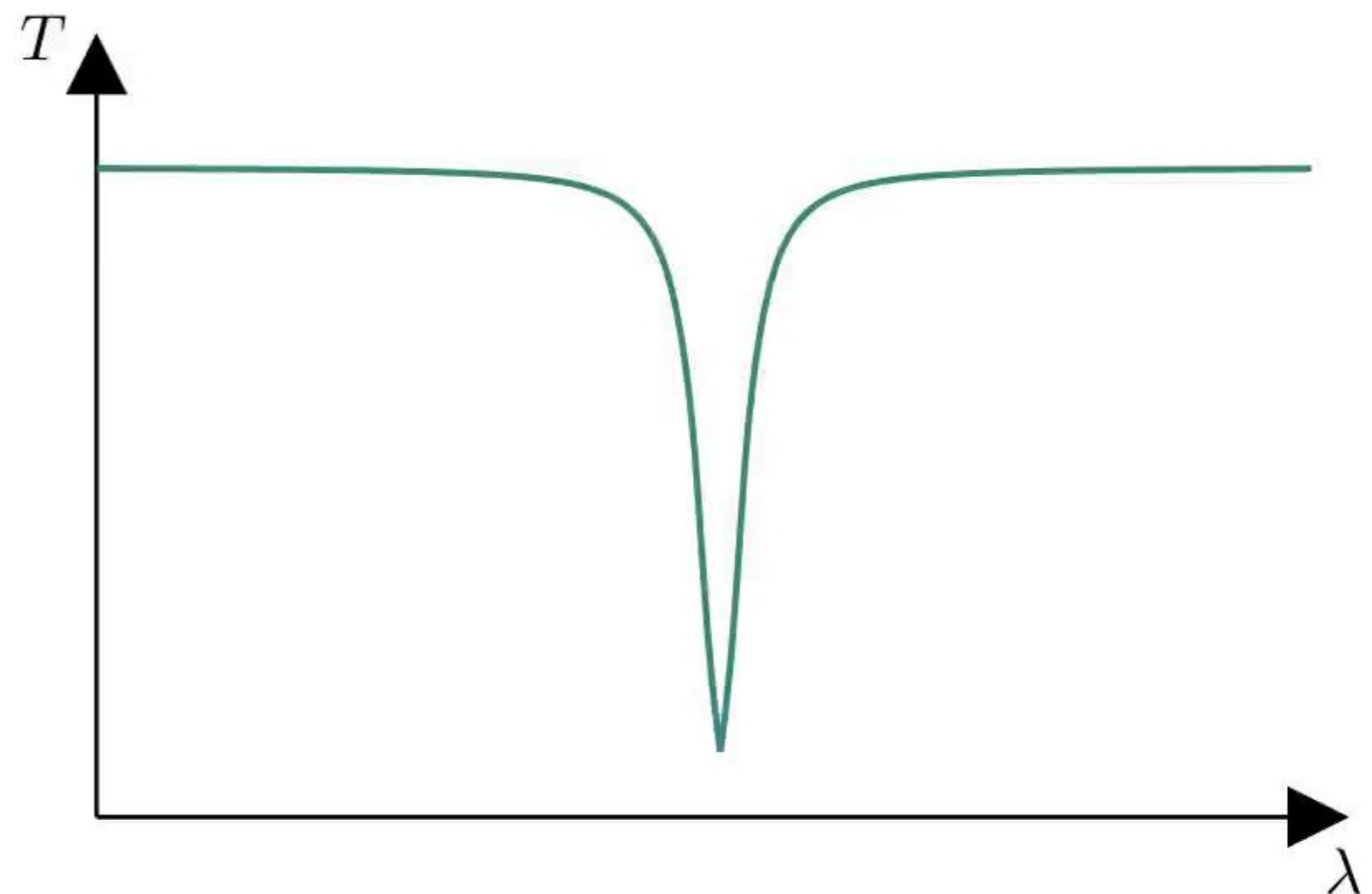
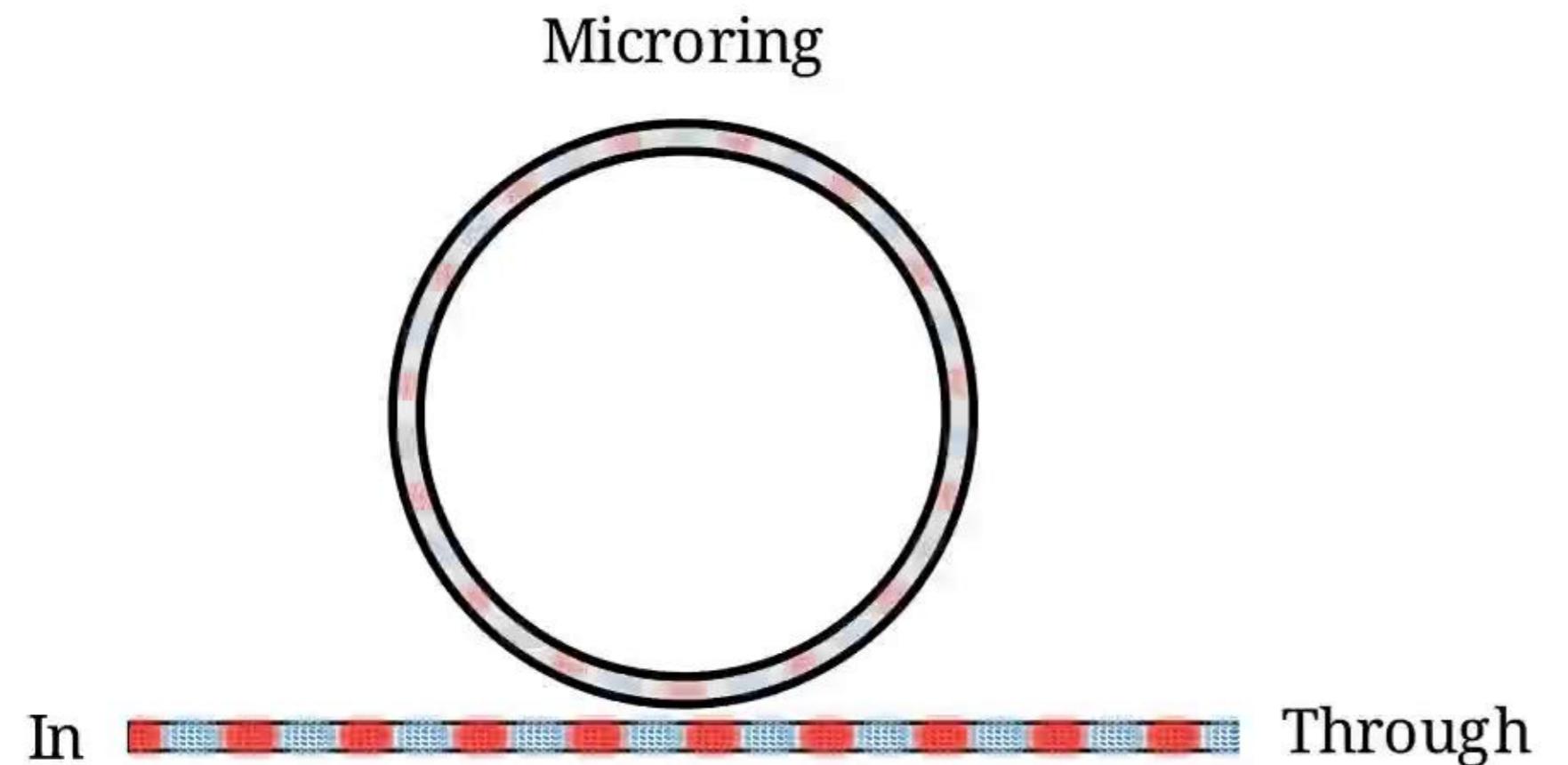


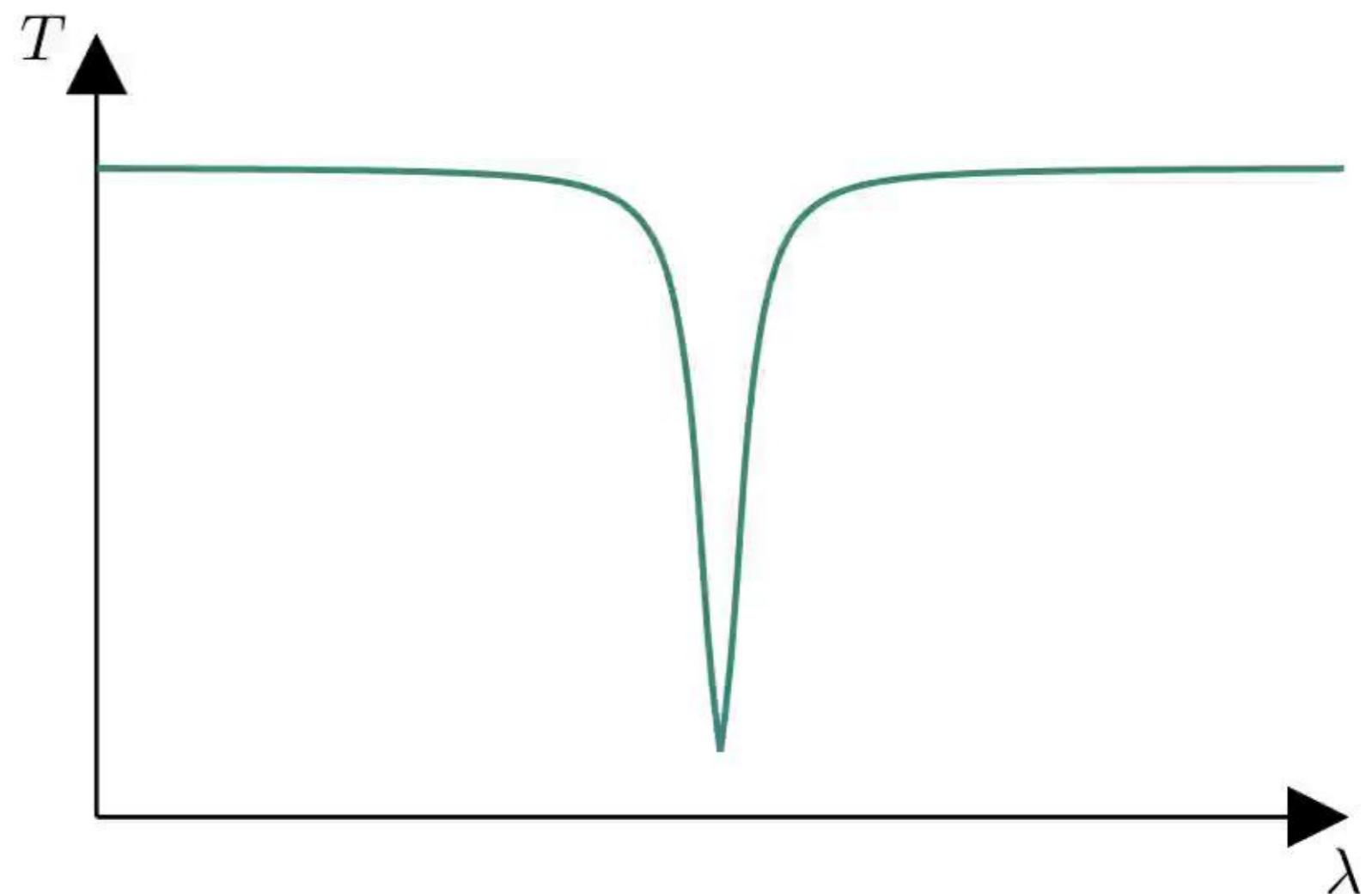
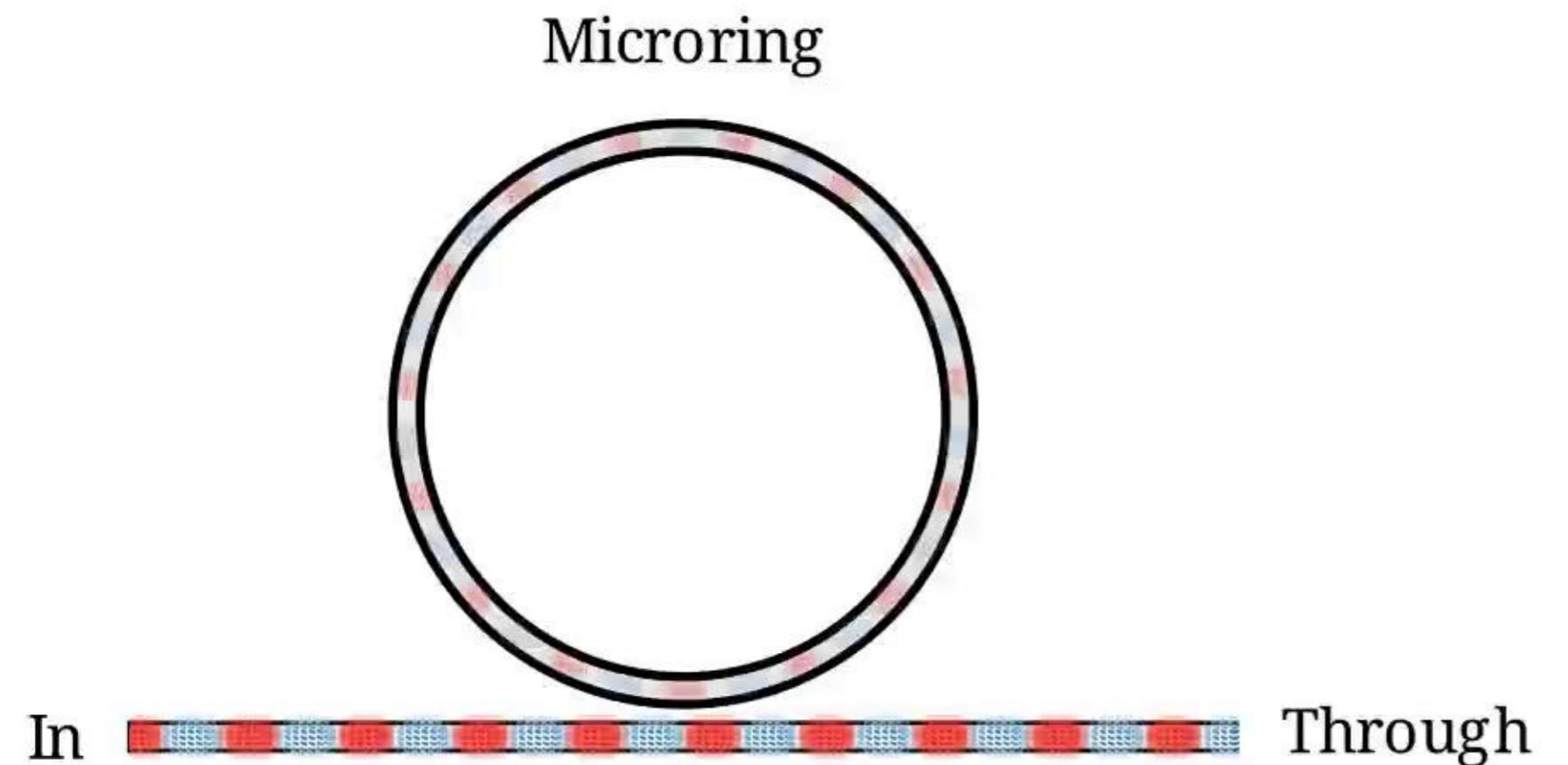




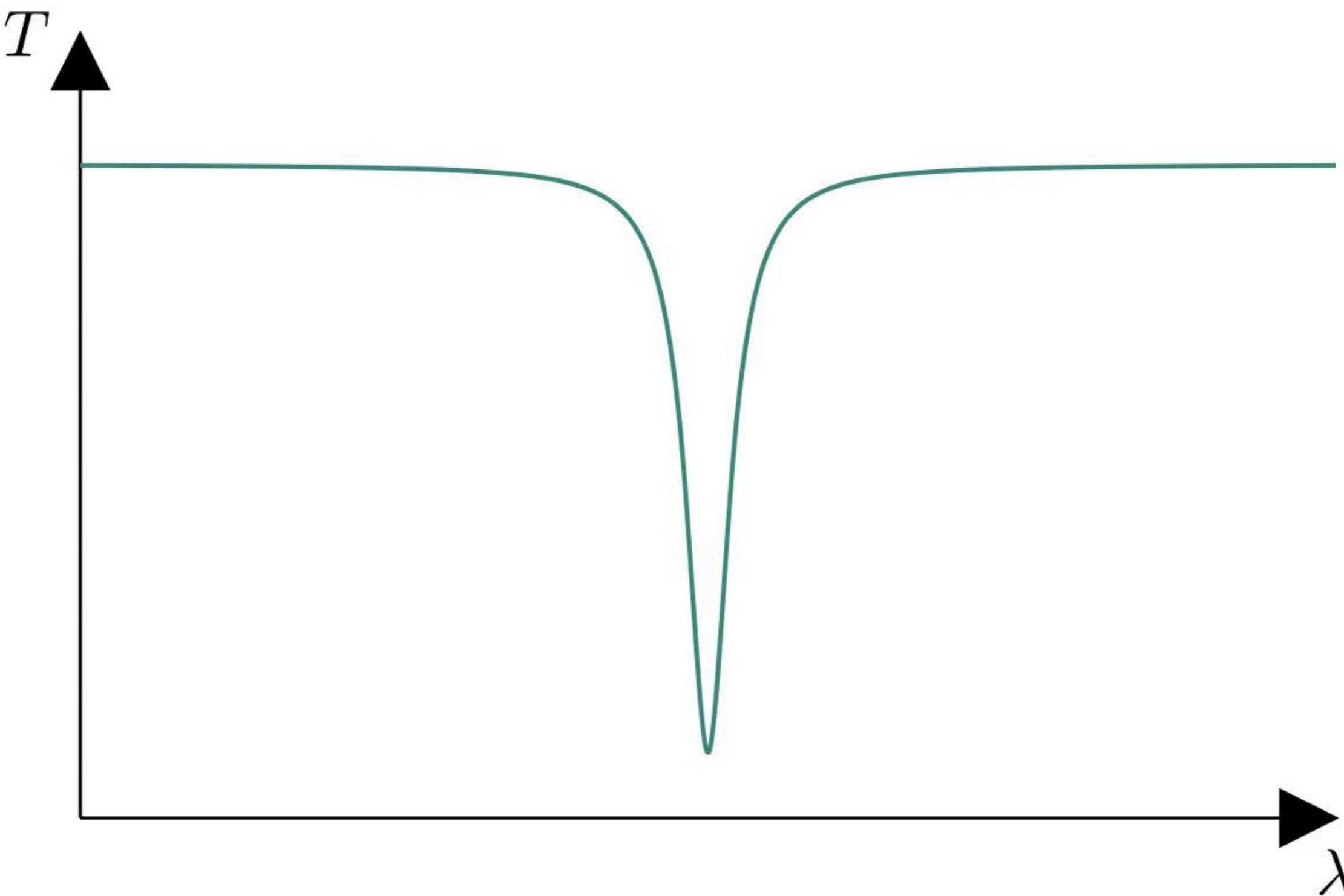




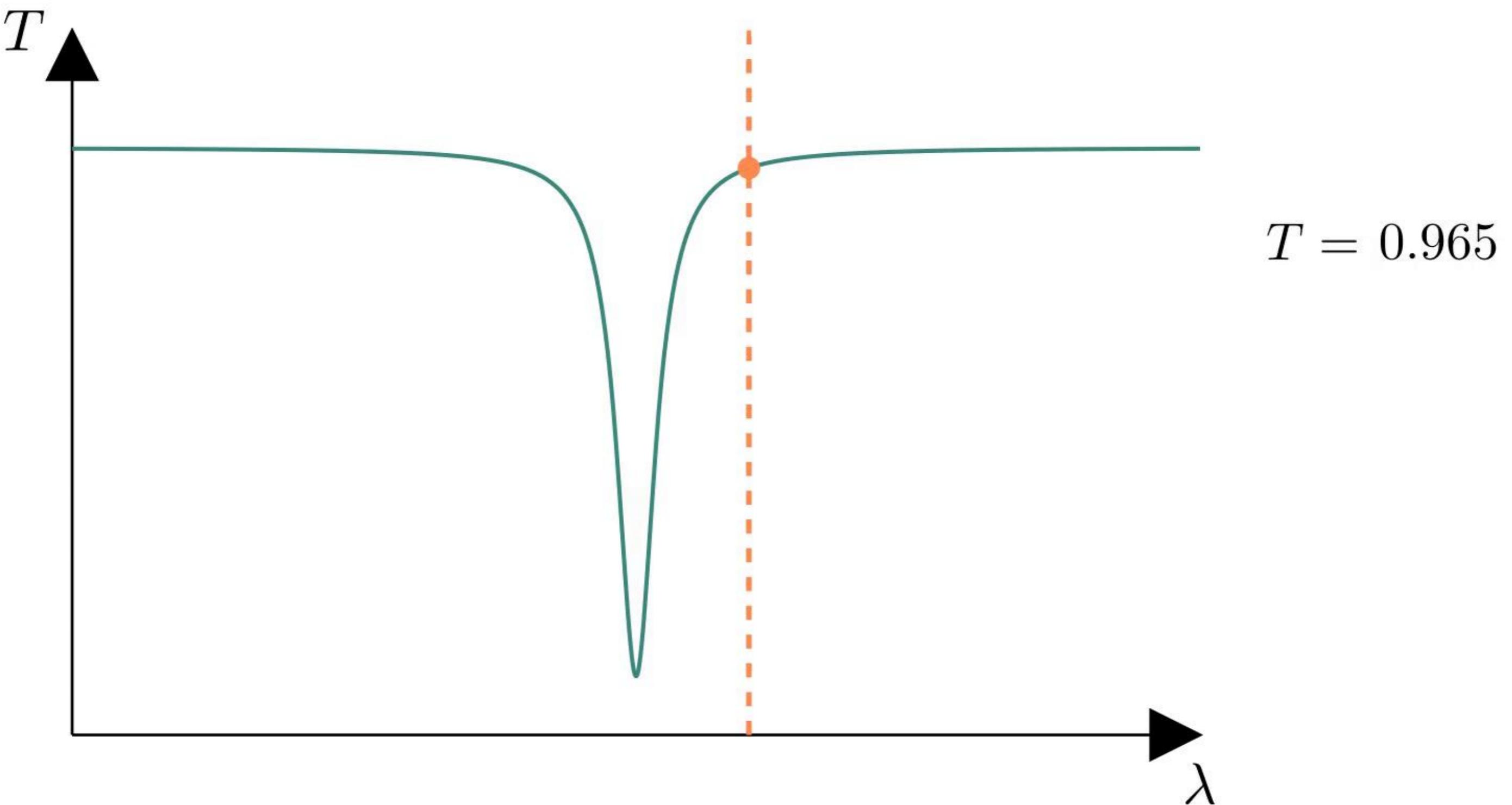




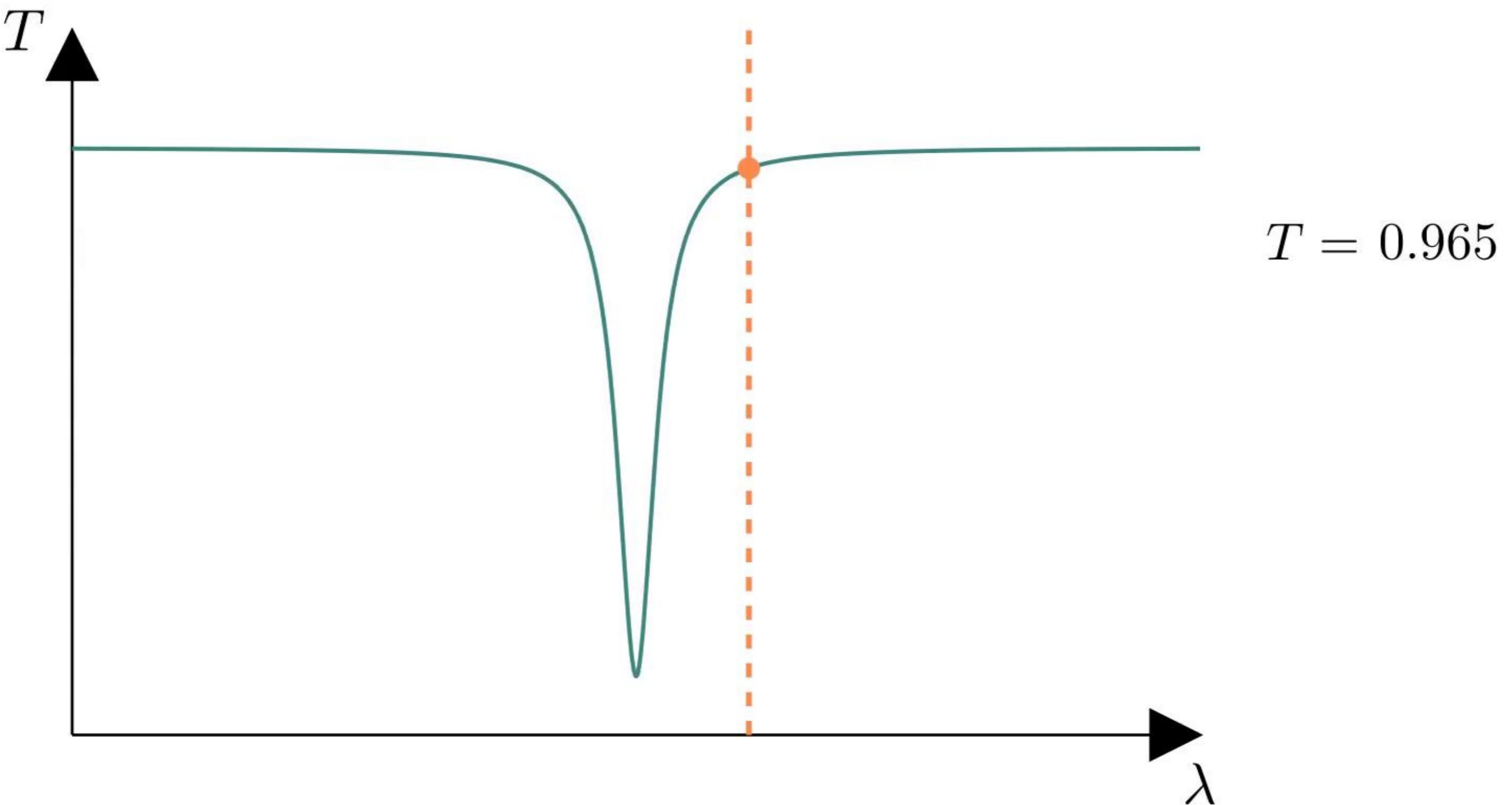
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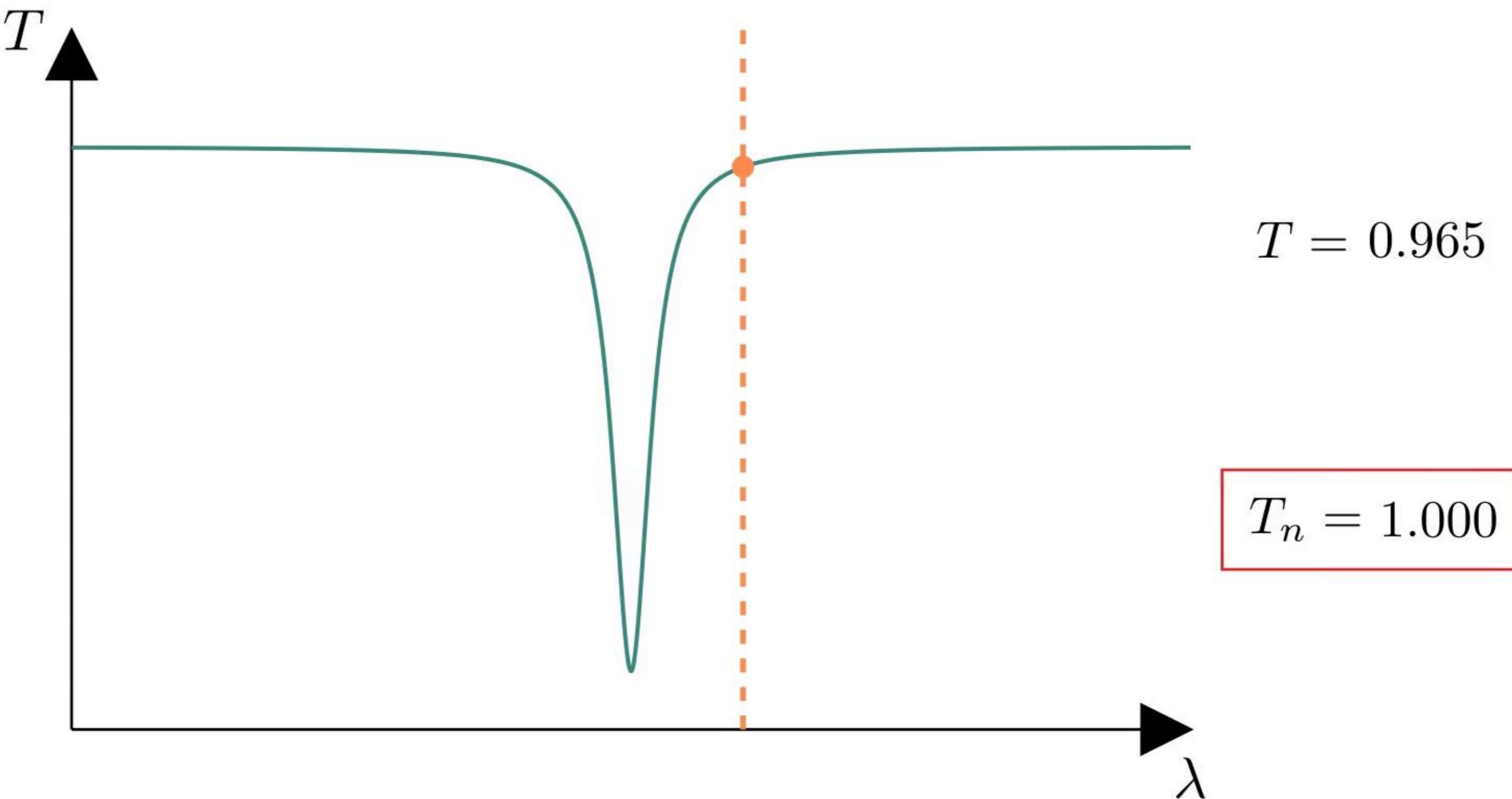
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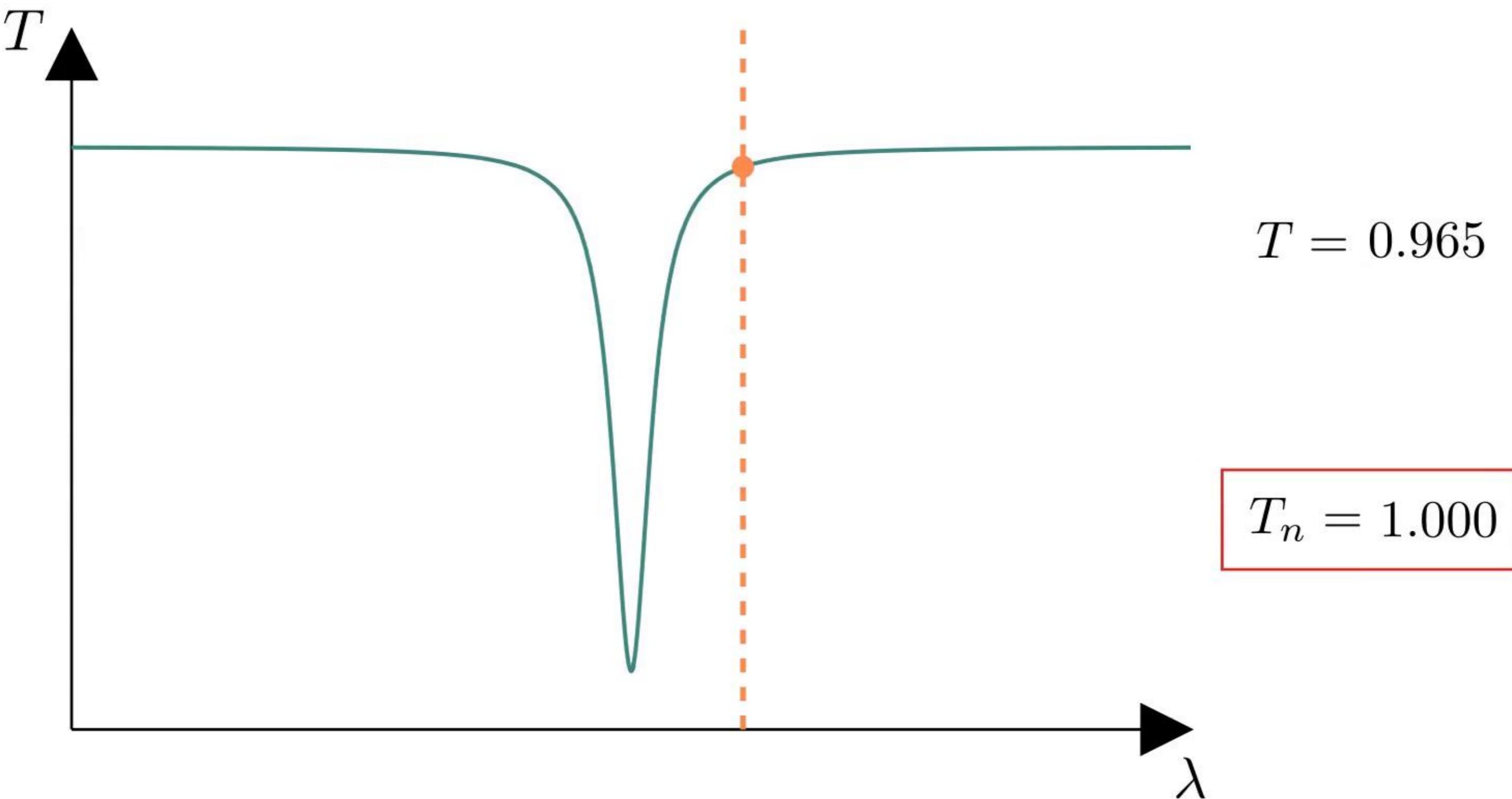
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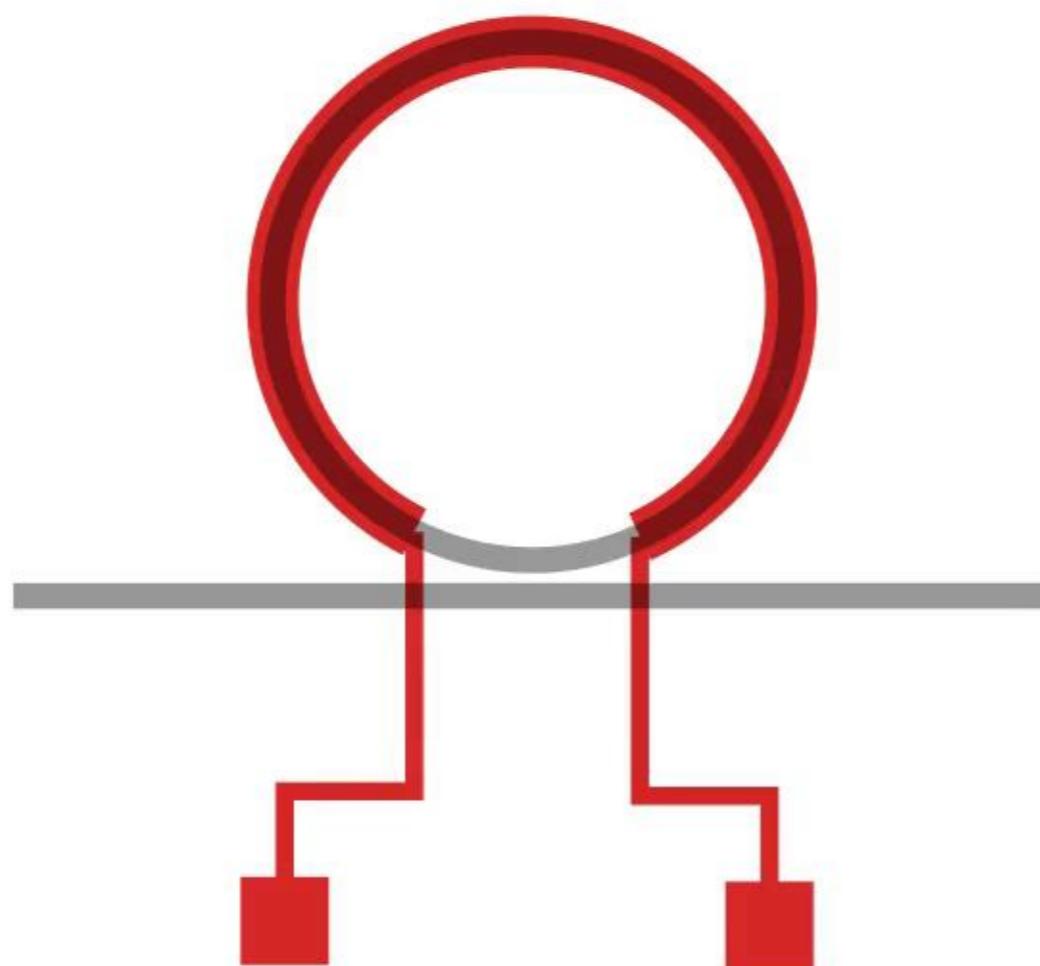
Why Kerr?



Modulation Types

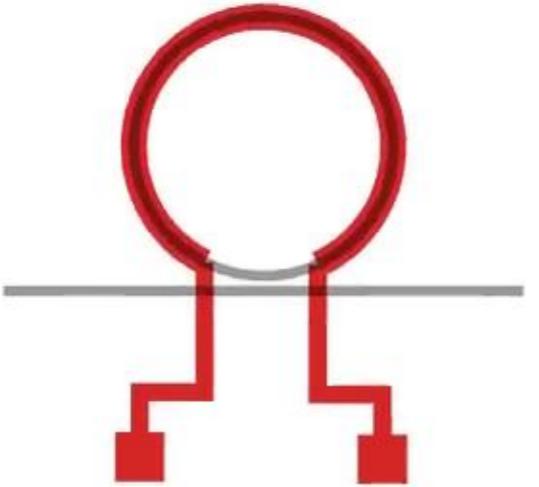
Modulation Types

Thermo-optic



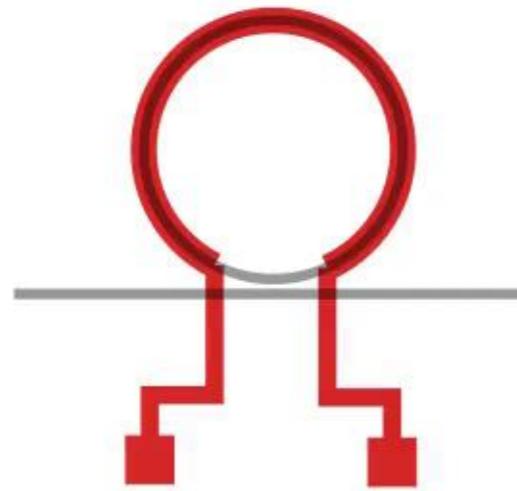
Modulation Types

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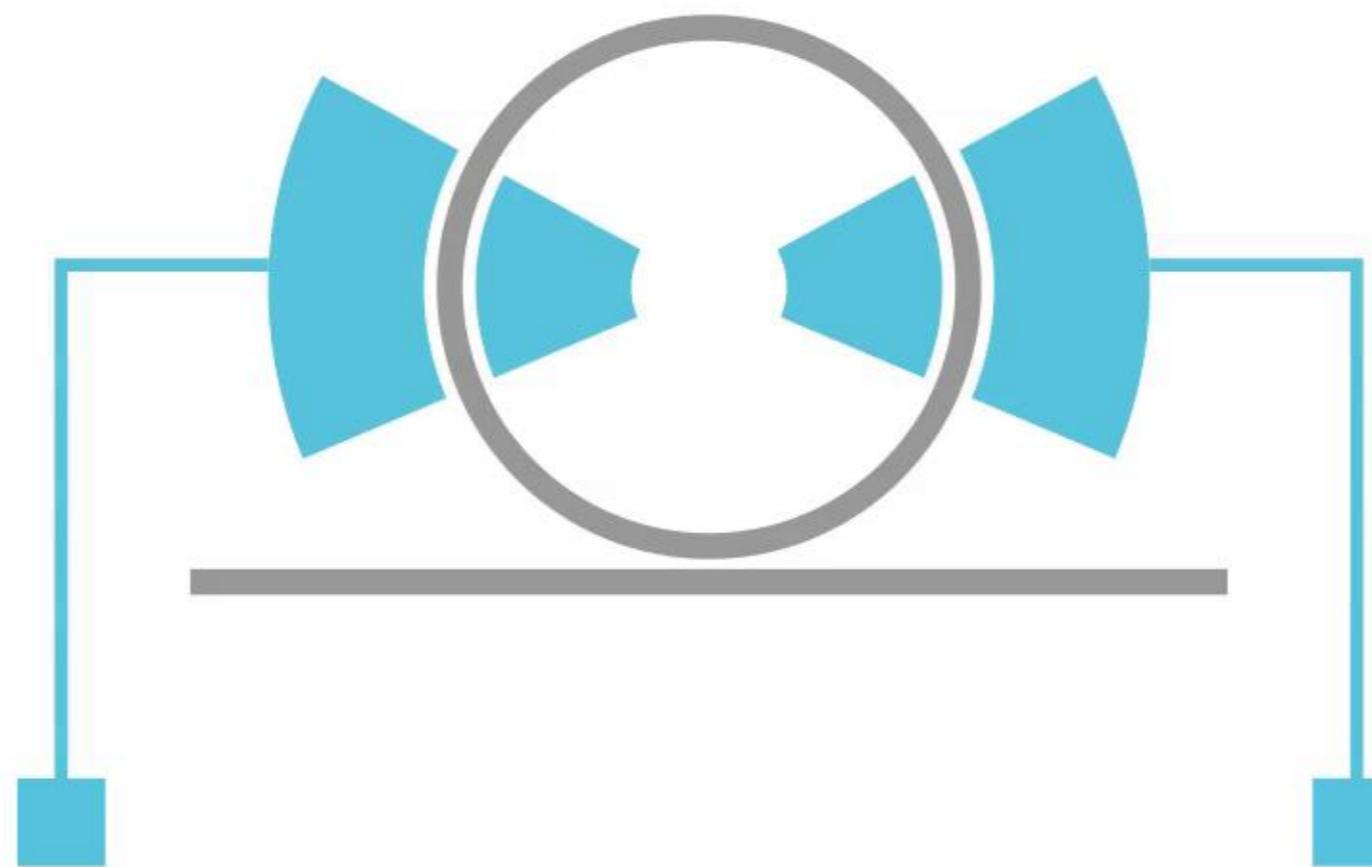


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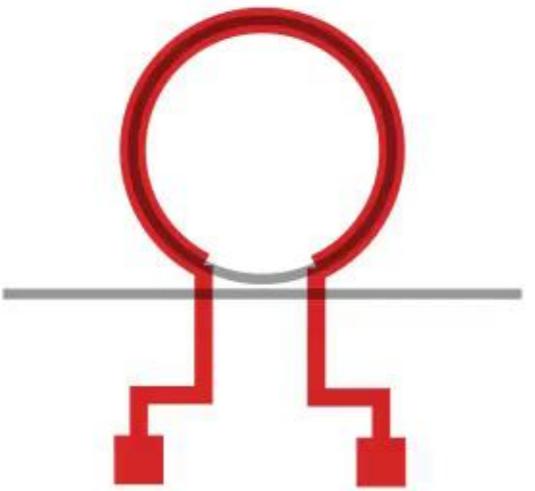


Electro-optic

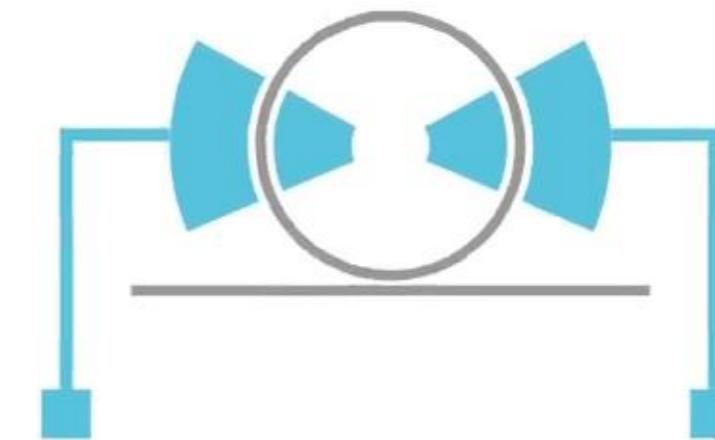


Modulation Types

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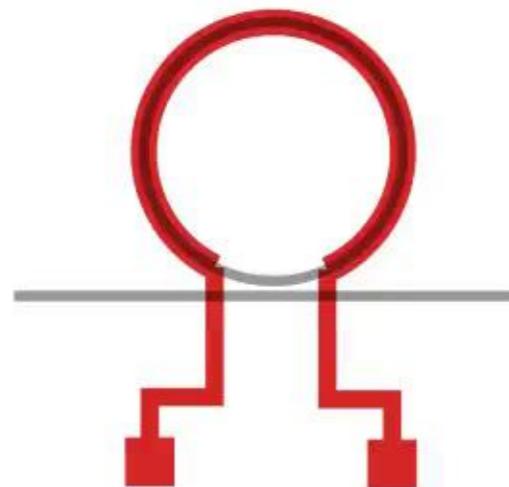


Electro-optic

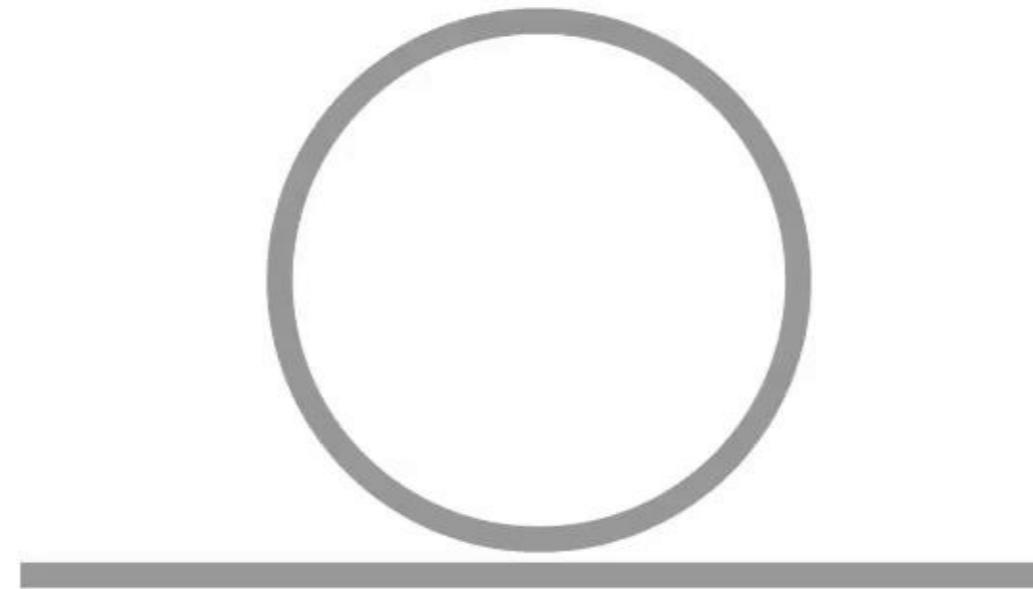
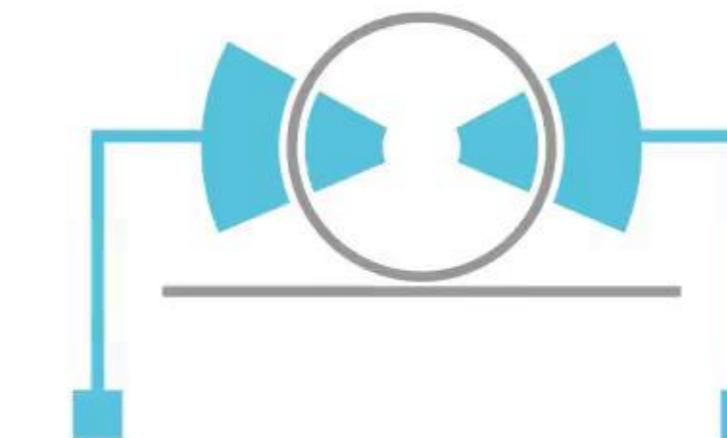


Modulation Types

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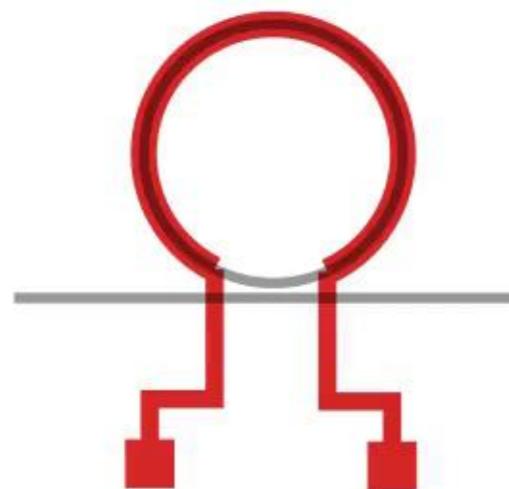


Electro-optic

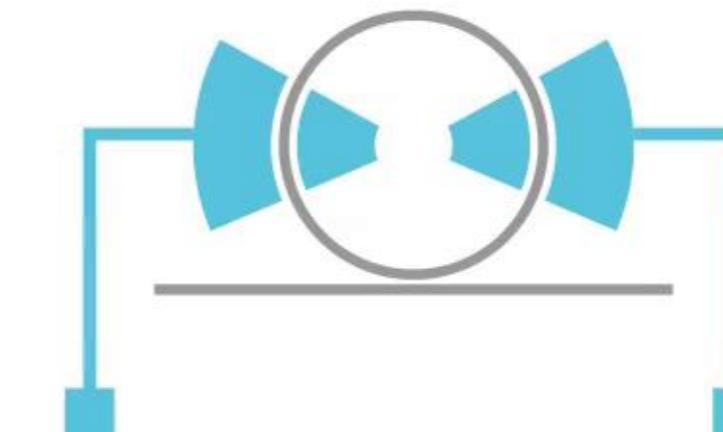


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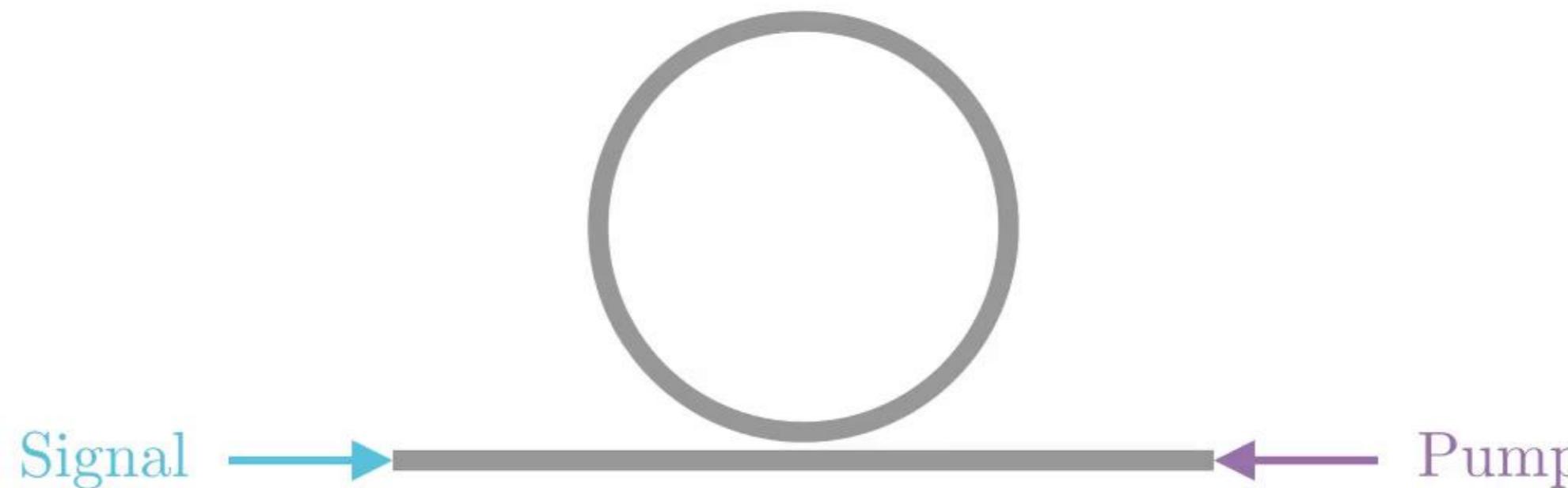
Thermo-optic



Electro-optic



All-optical



Optical Kerr Effect

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$$n = n_0 + n_2 I$$

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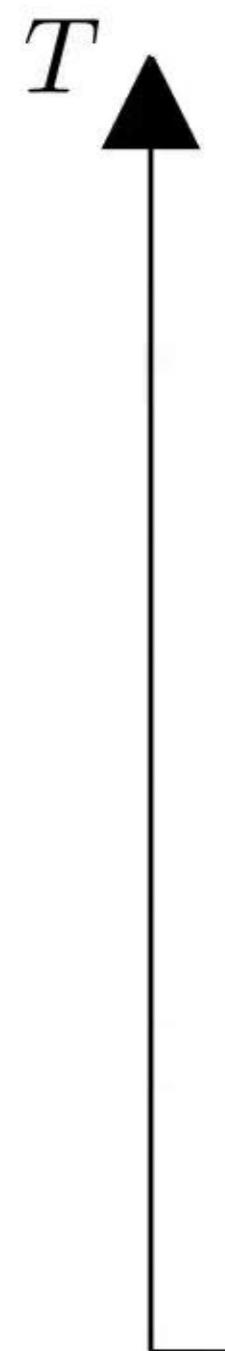
$$n_2 = \frac{3\Re[\chi^{(3)}]}{4n_0^2\epsilon_0 c}$$

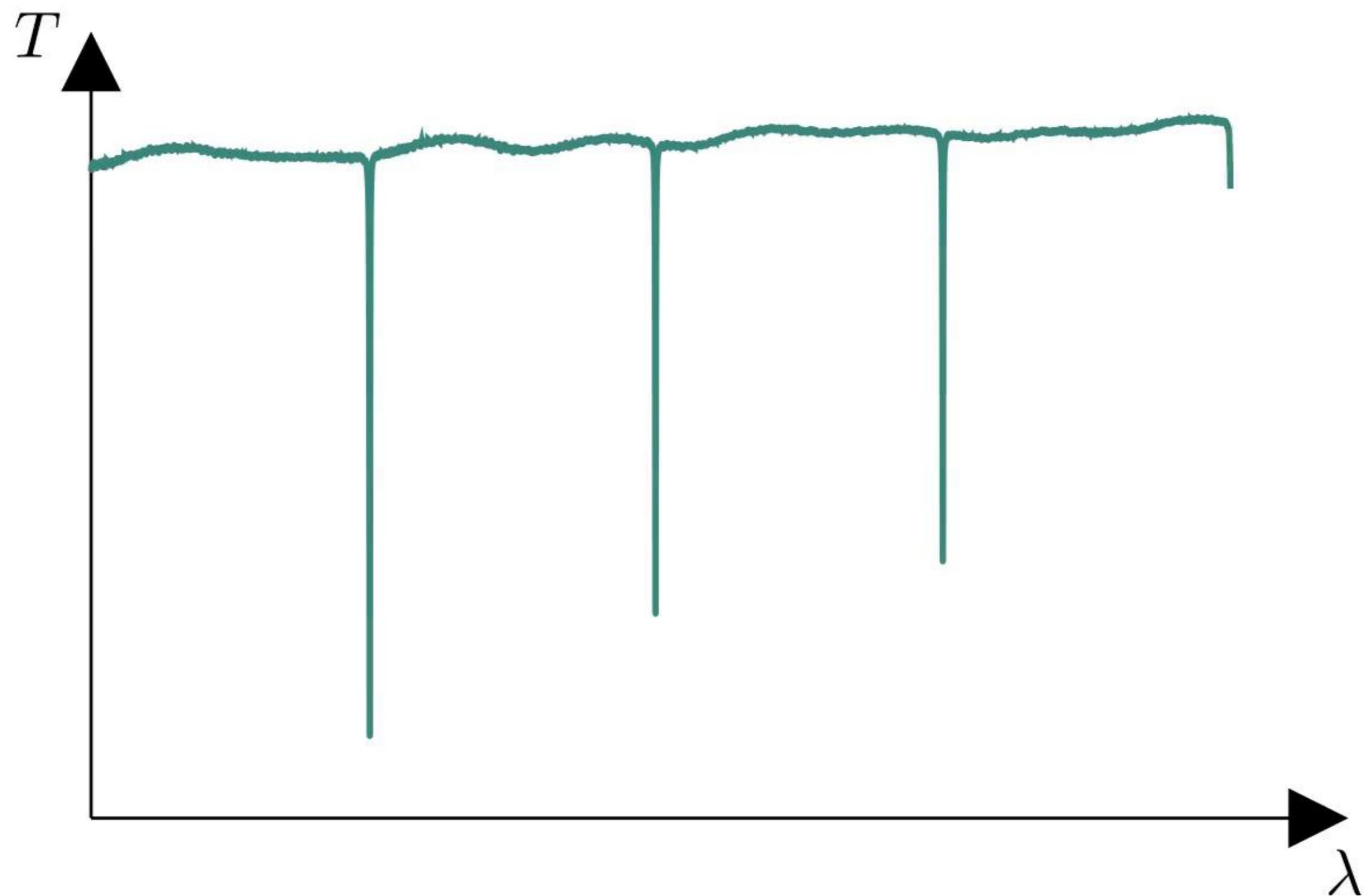
Optical Kerr Effect

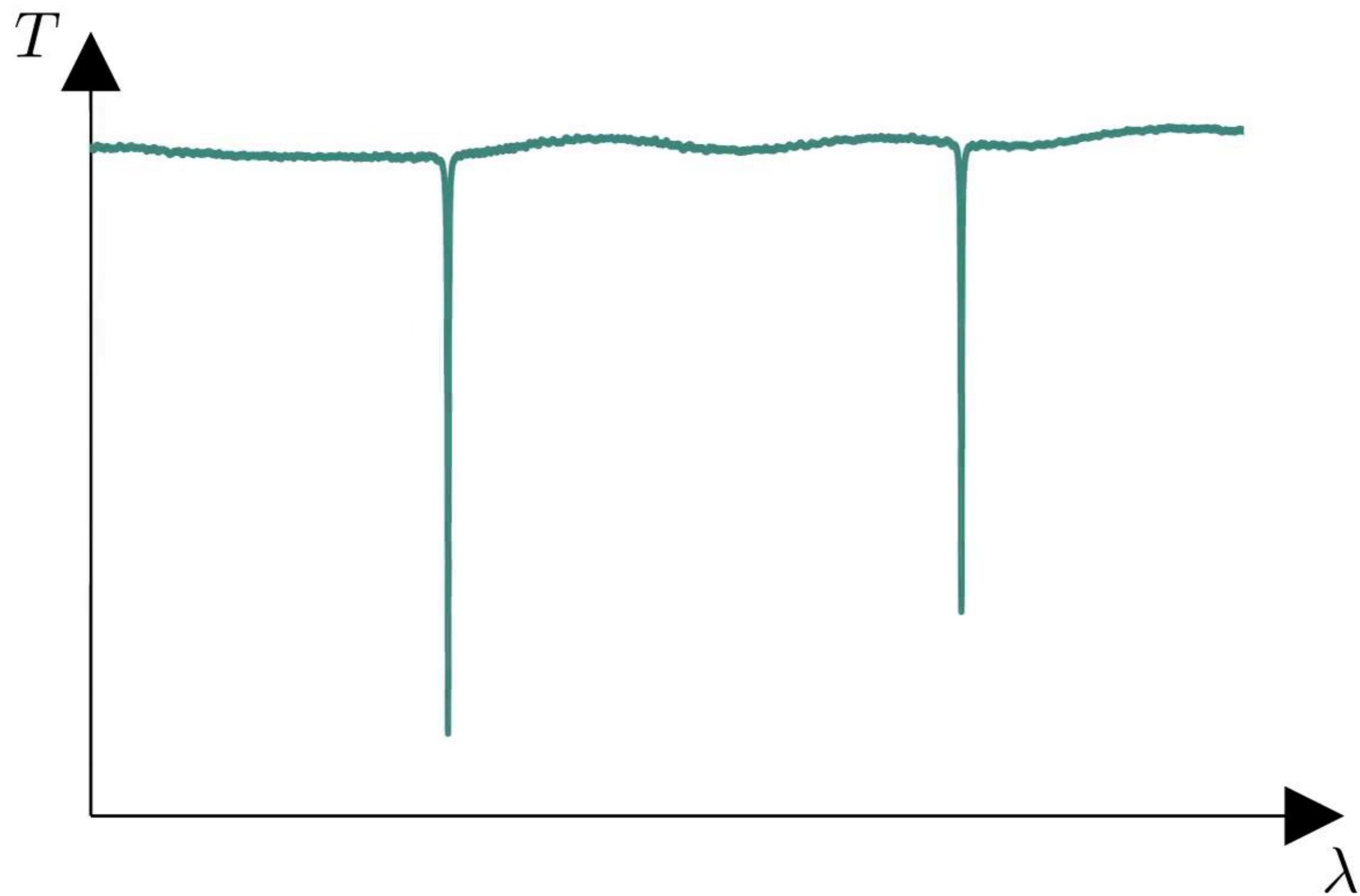
$$n = n_0 + n_2 I$$

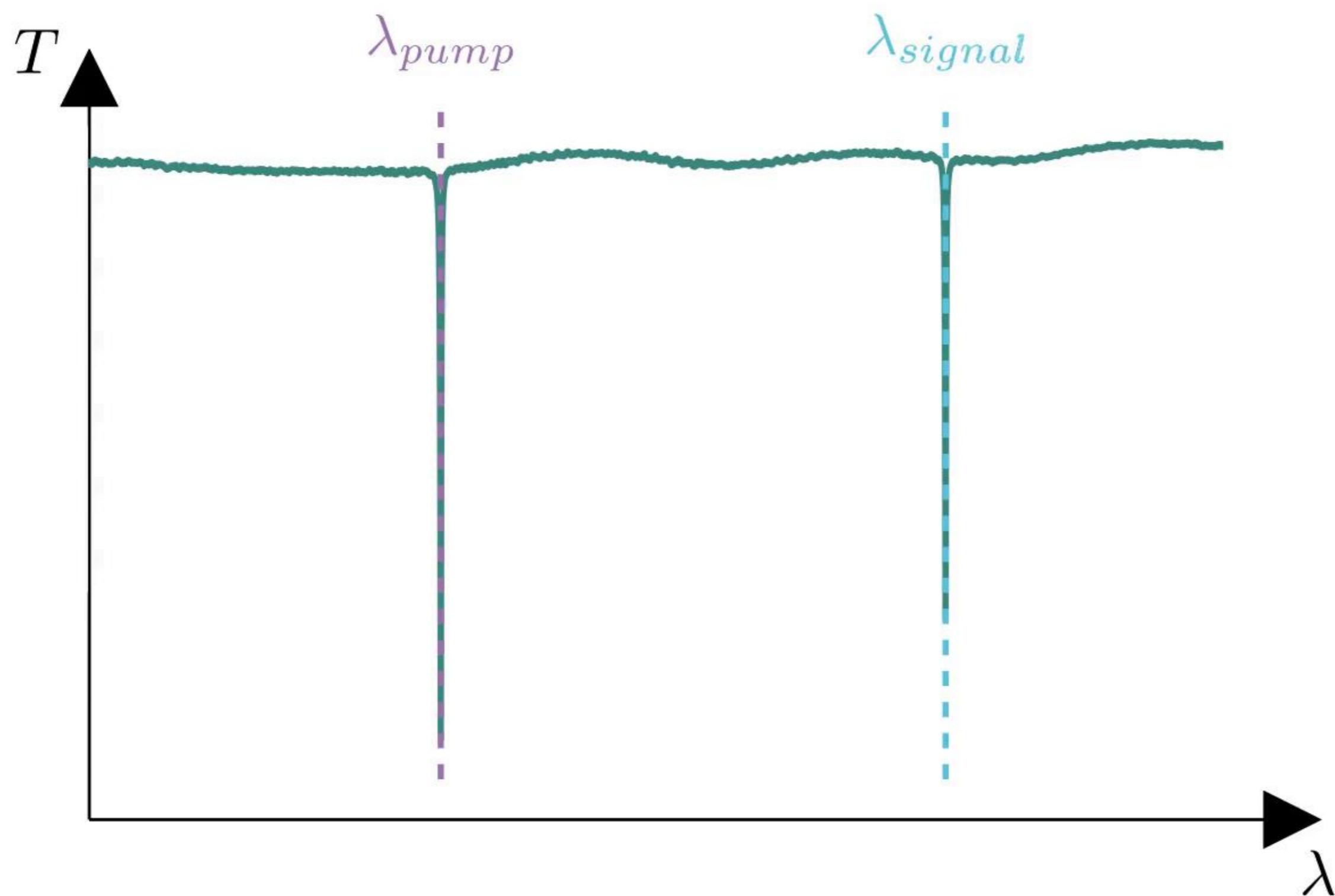
$$n_2=\frac{3\Re[\chi^{(3)}]}{4n_0^2\epsilon_0 c}$$

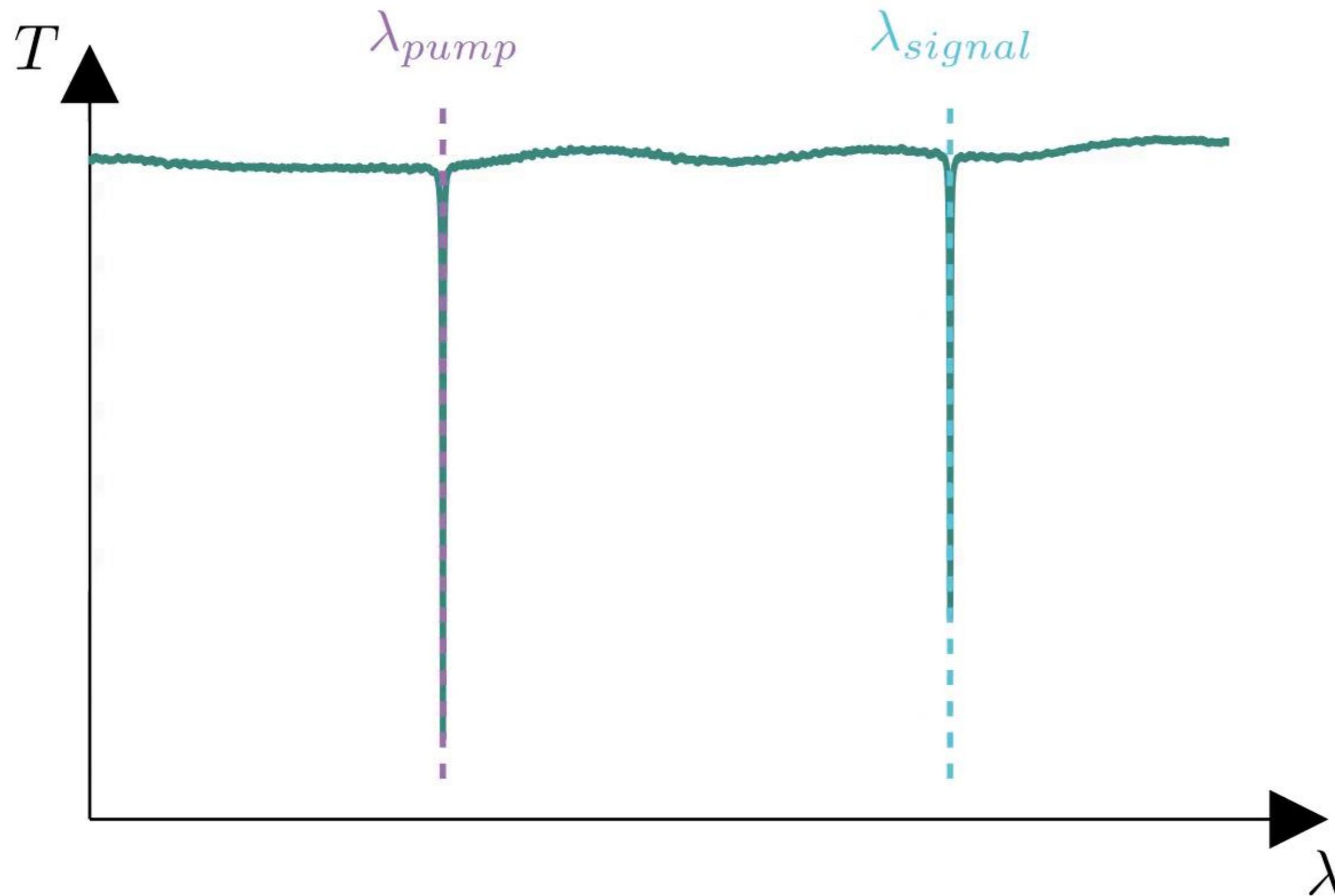
$$\Delta n=n_2I_{\mathrm{eff}}$$





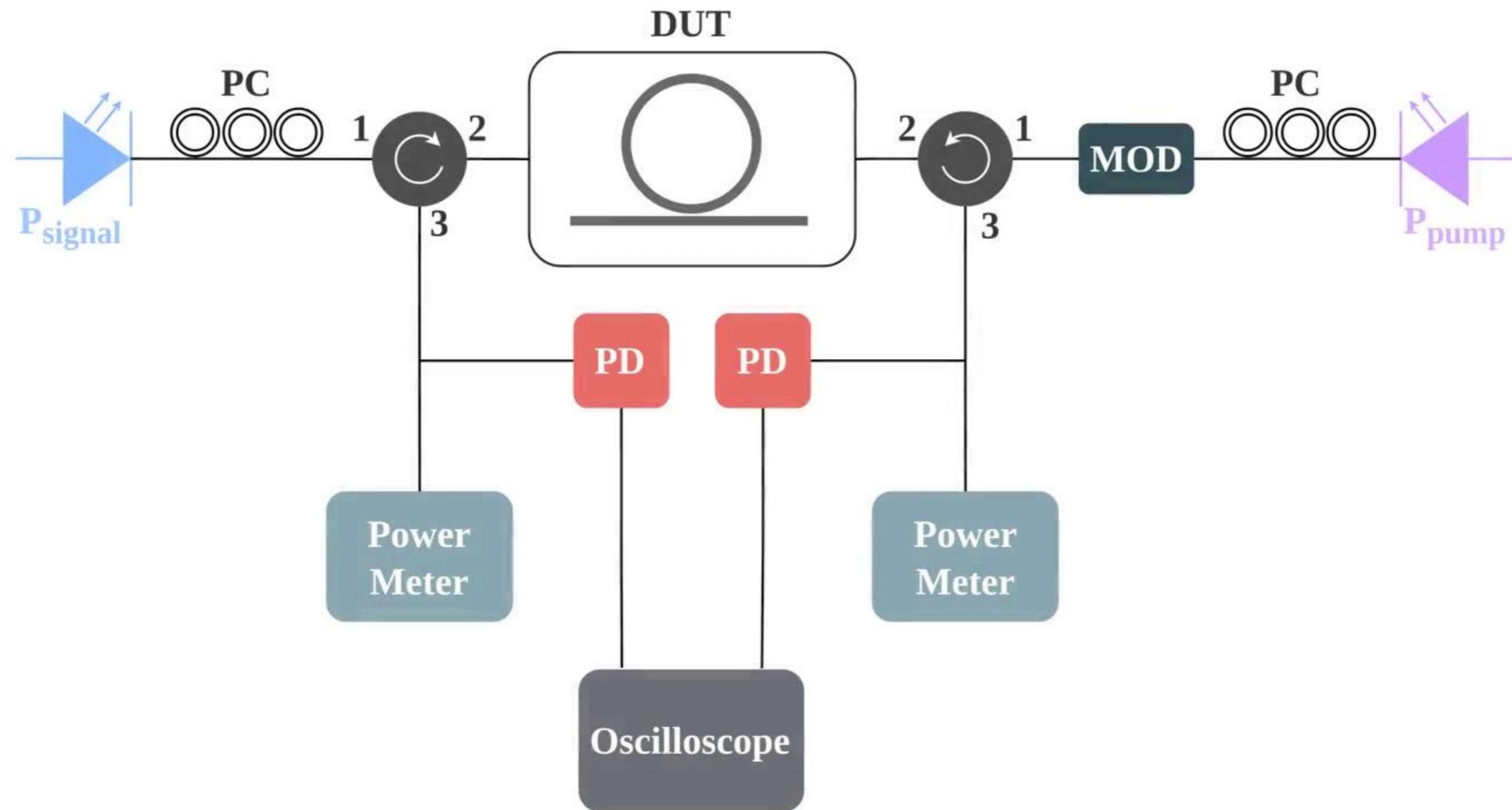




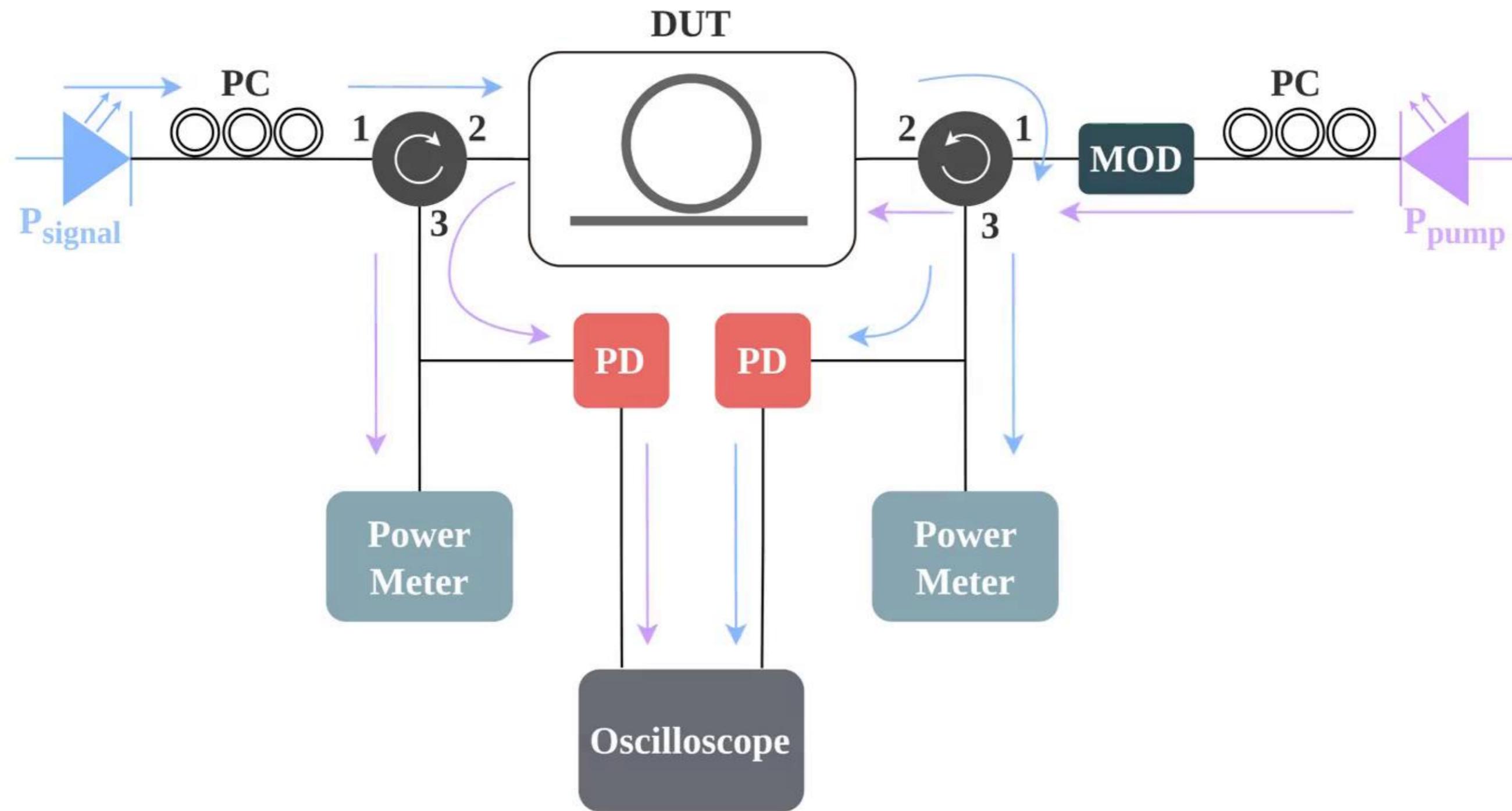


Experiment Setup

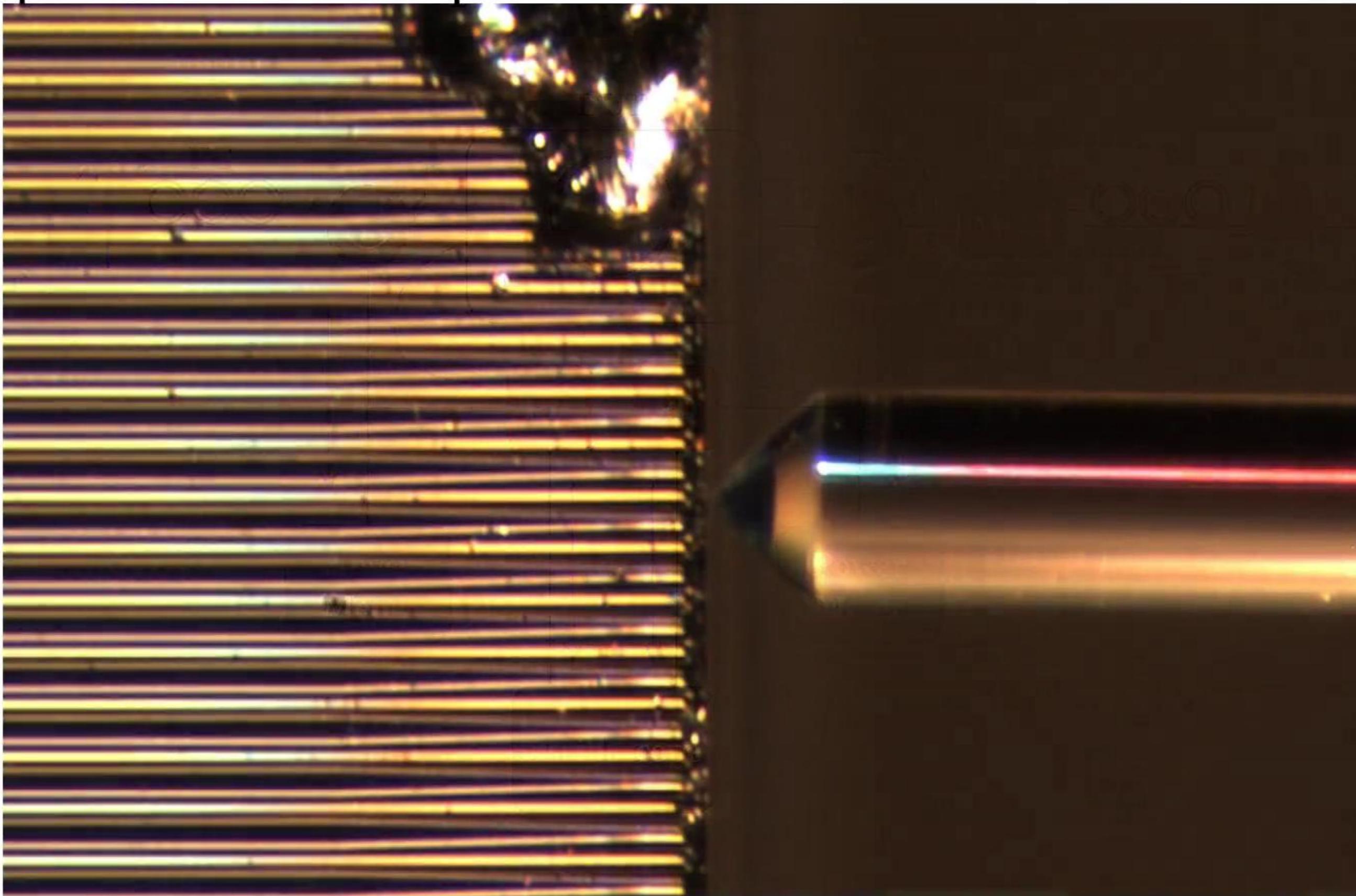
Experiment Setup



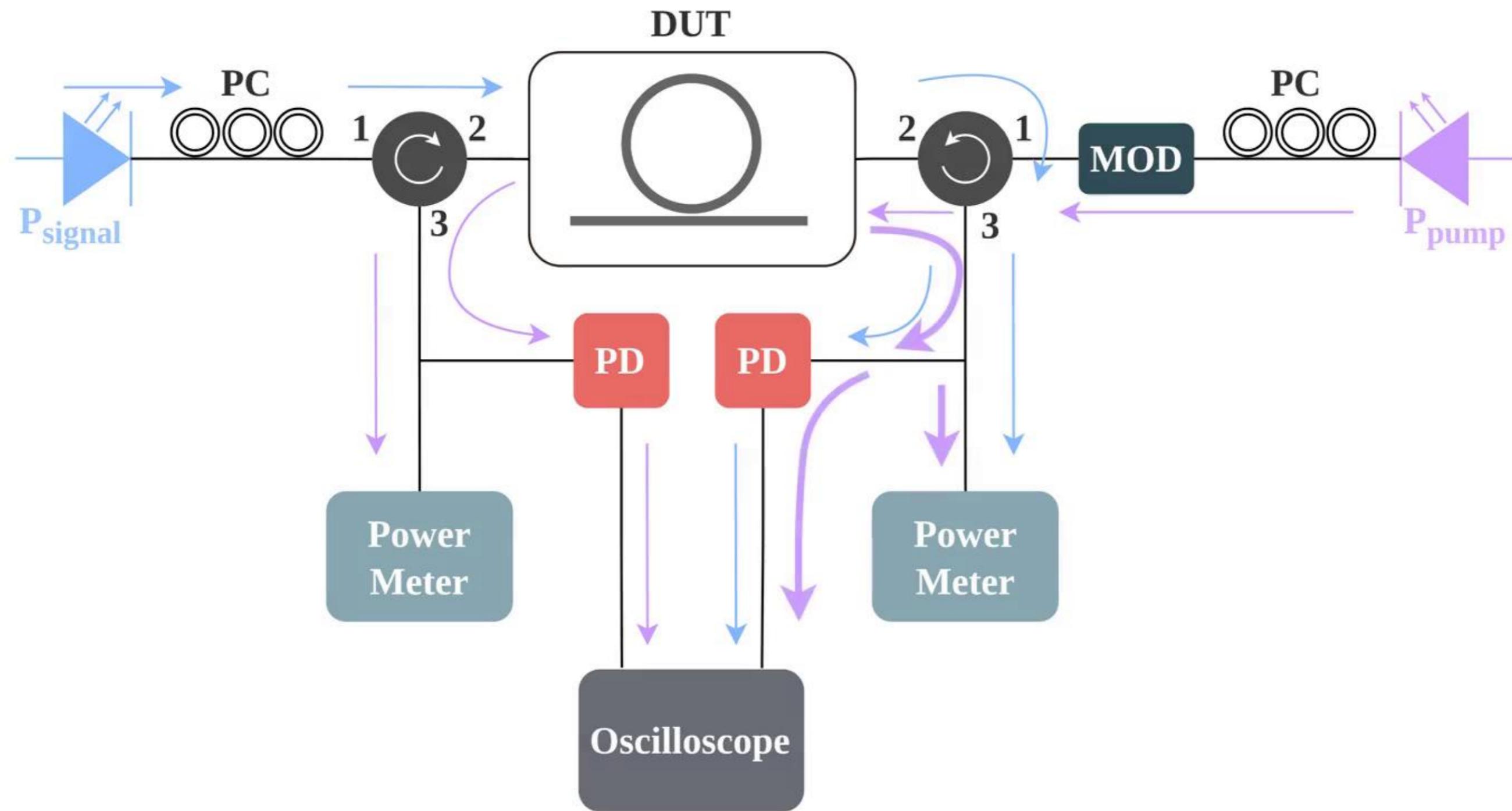
Experiment Setup

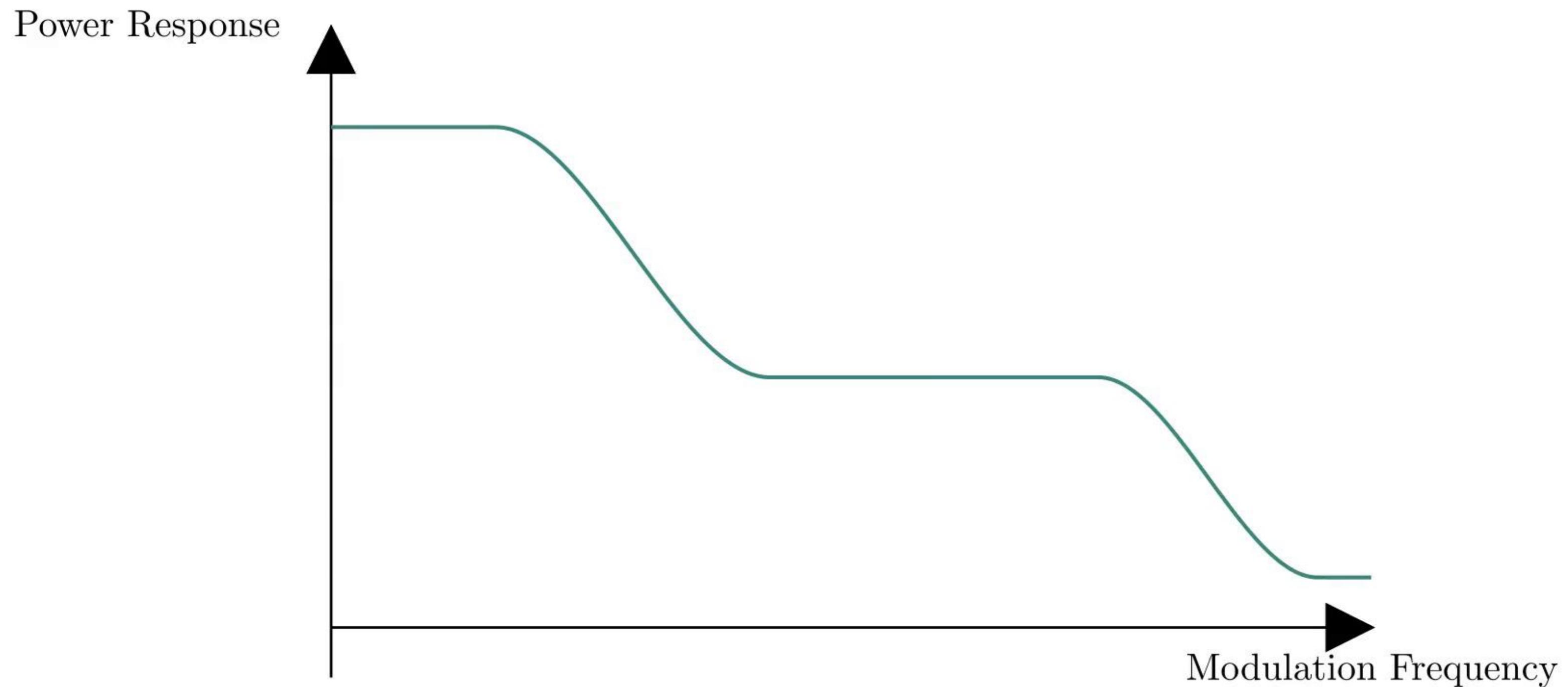


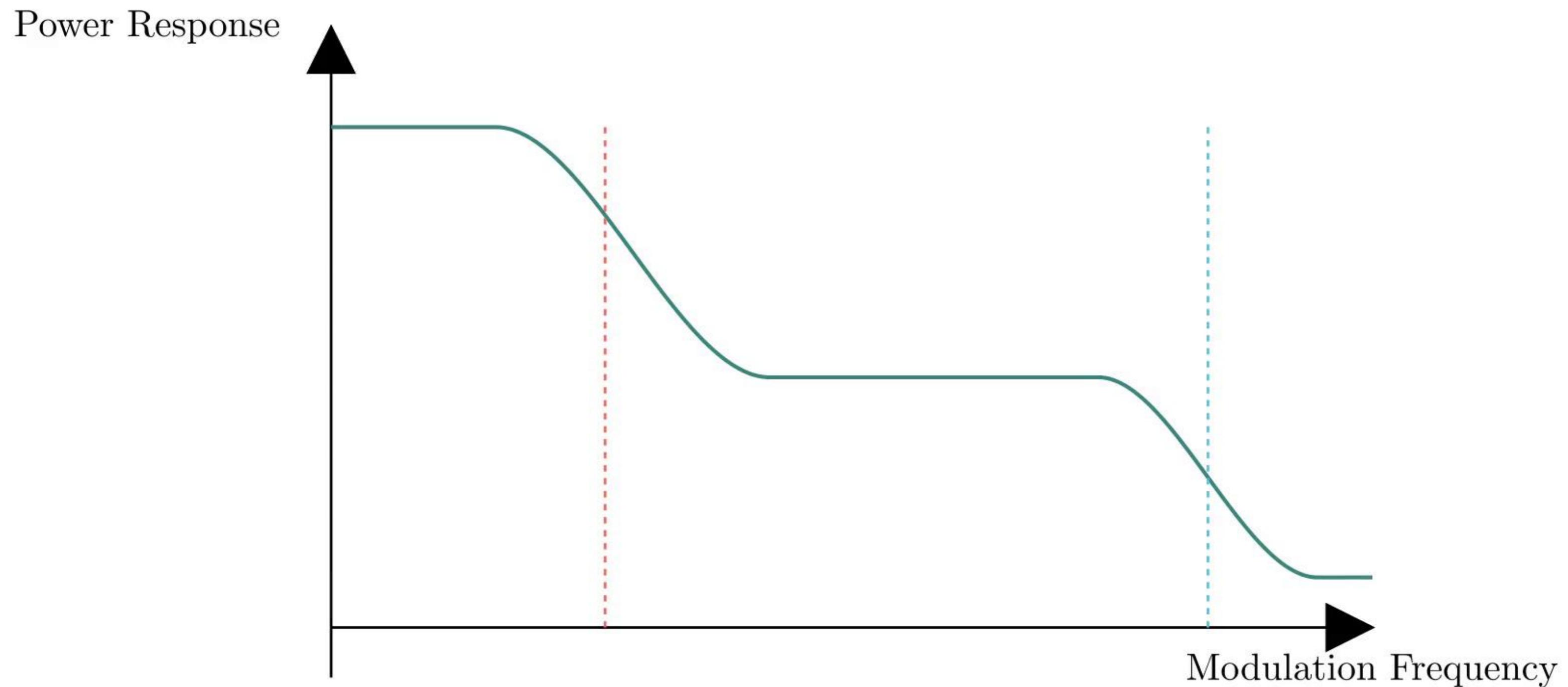
Experiment Setup

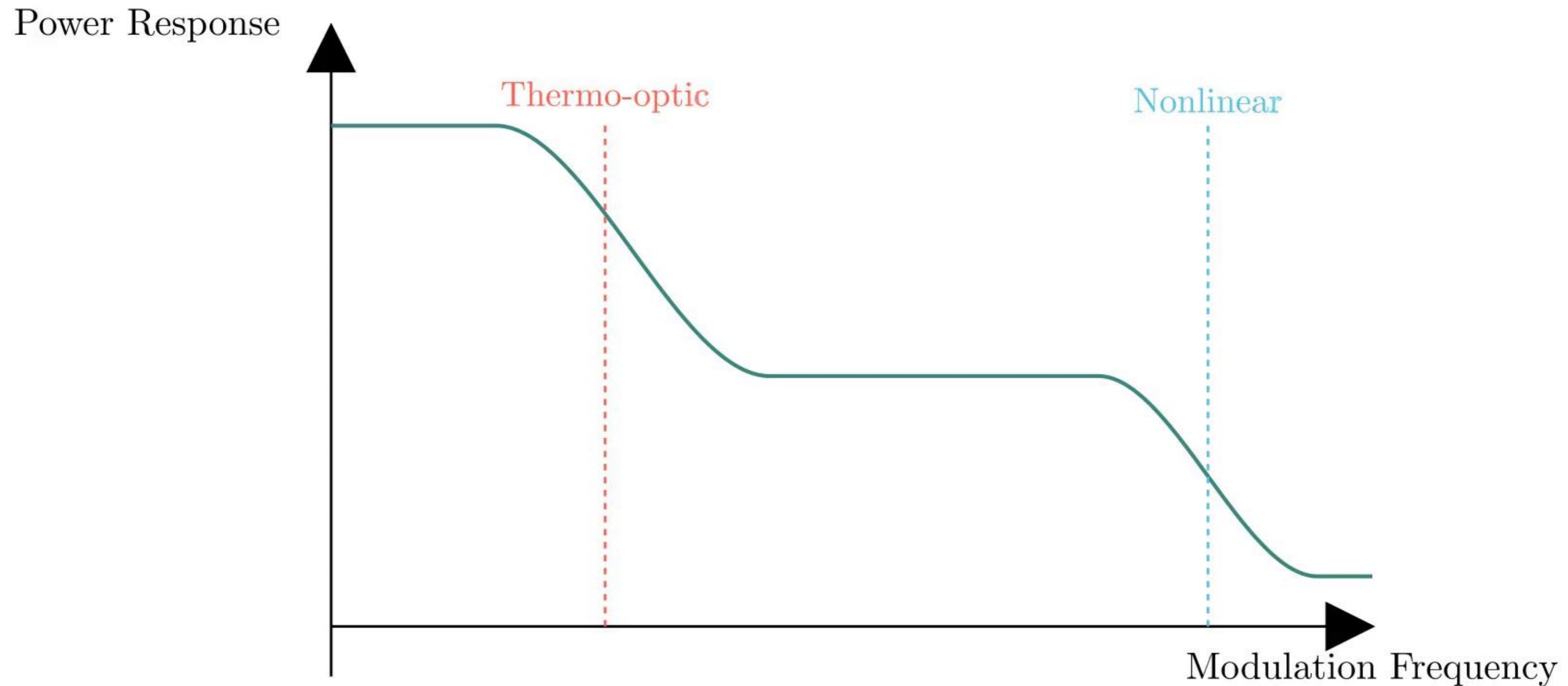


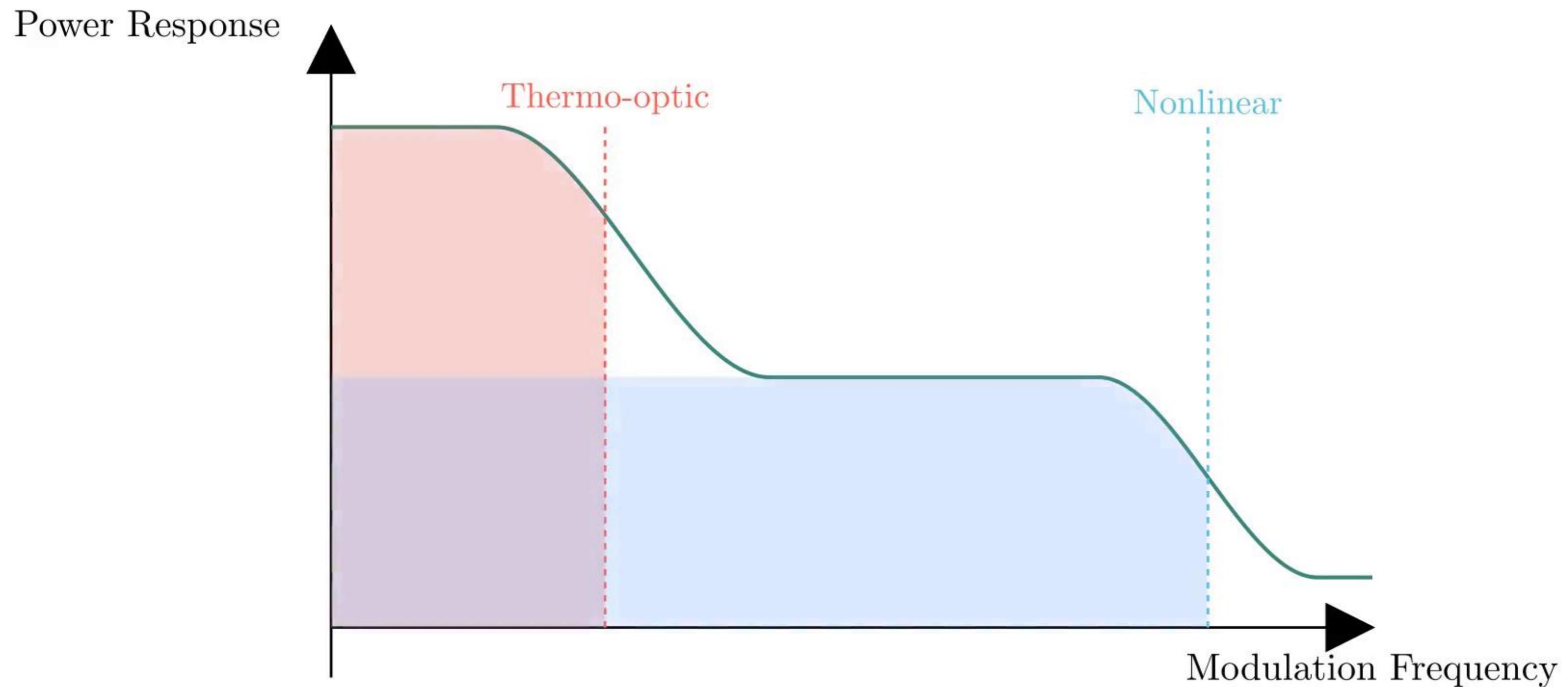
Experiment Setup





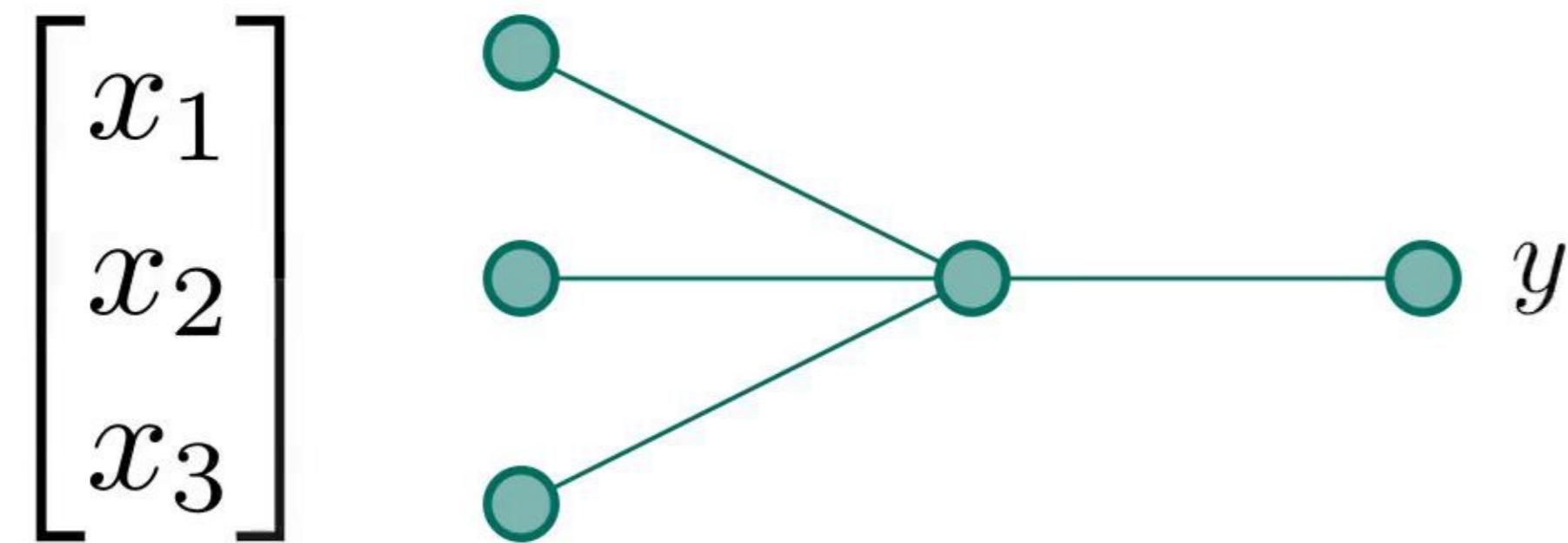




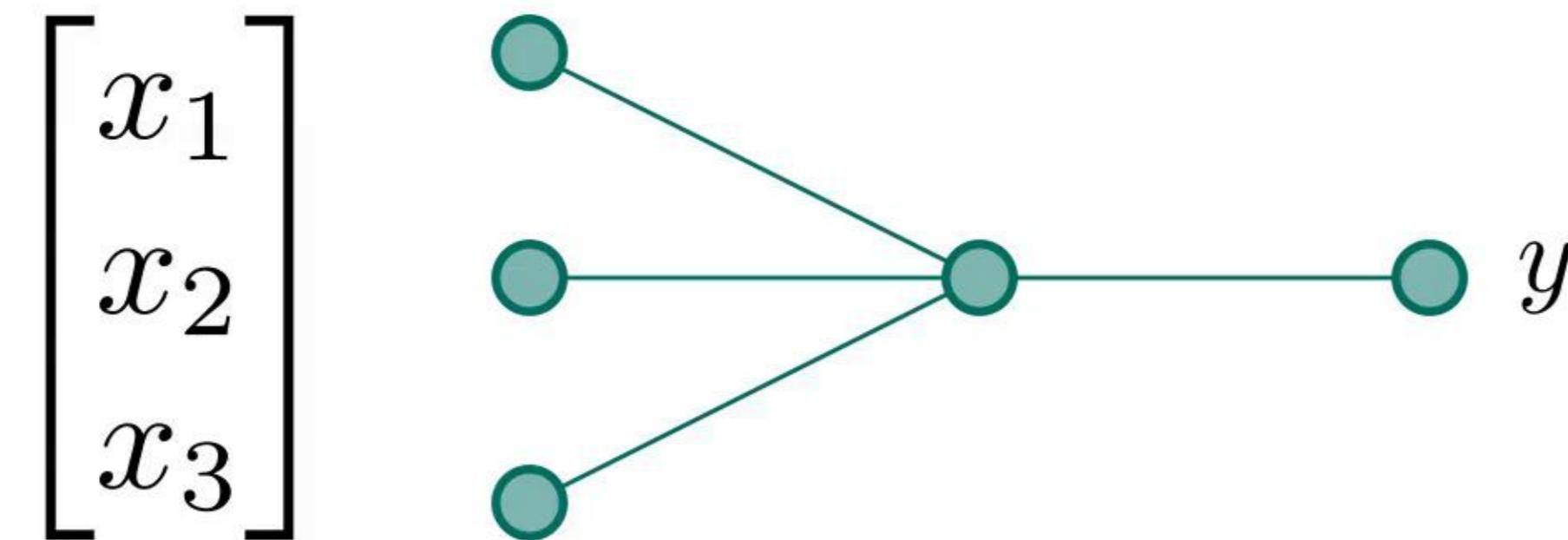


Application

Neuron



Neuron



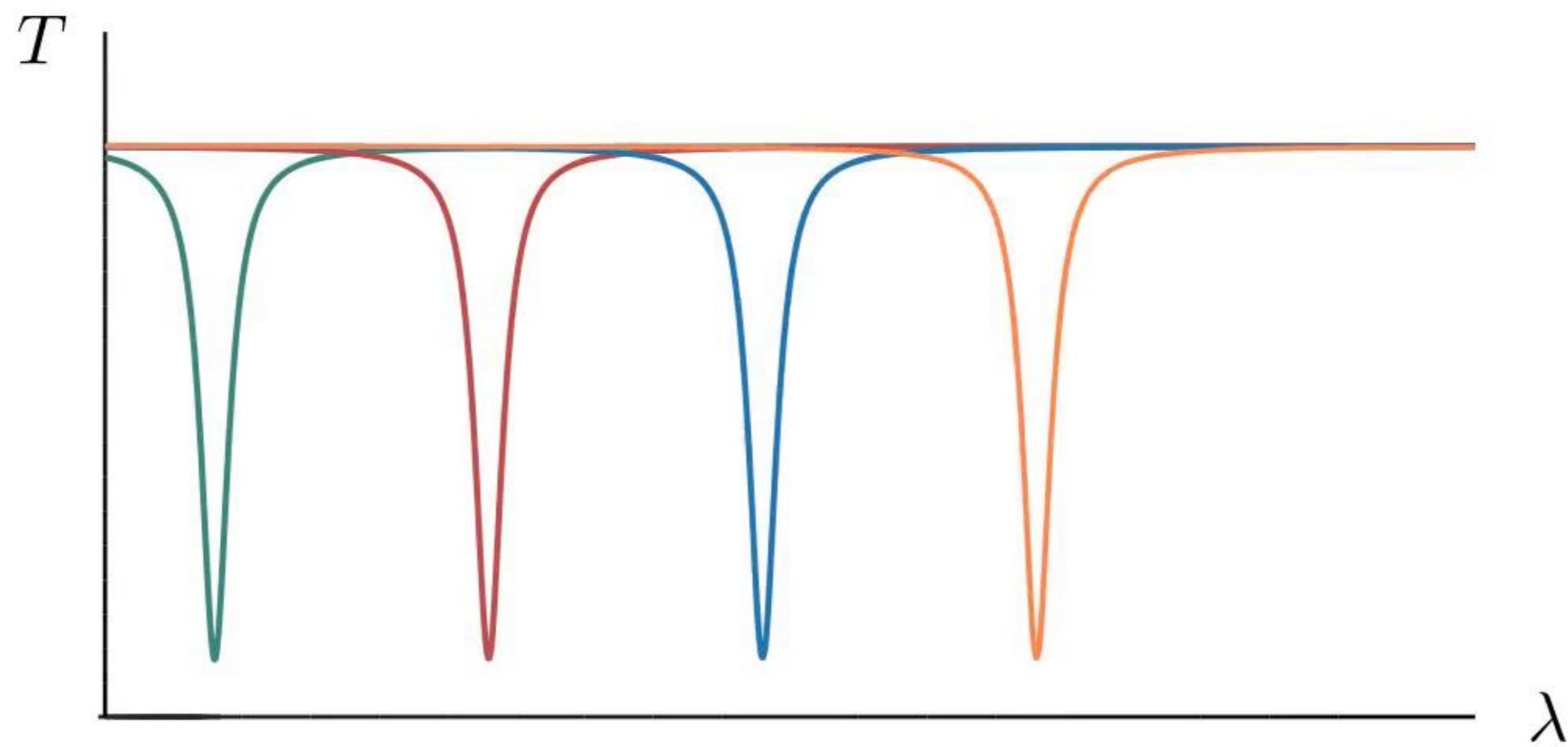
$$y = a(x_1w_1 + x_2w_2 + x_3w_3 + w_4)$$

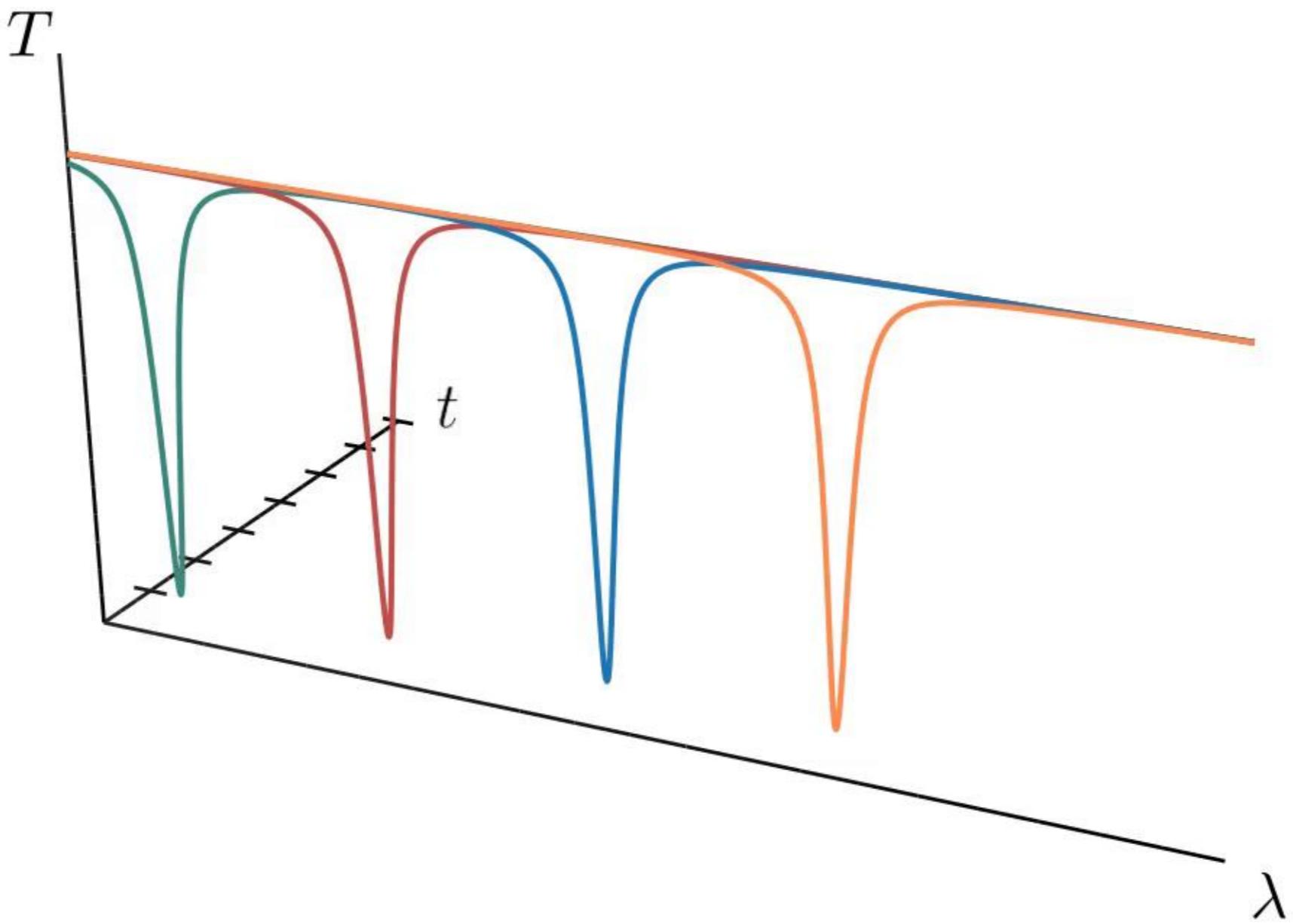
$$y=a(x_1w_1+x_2w_2+x_3w_3+w_4)$$

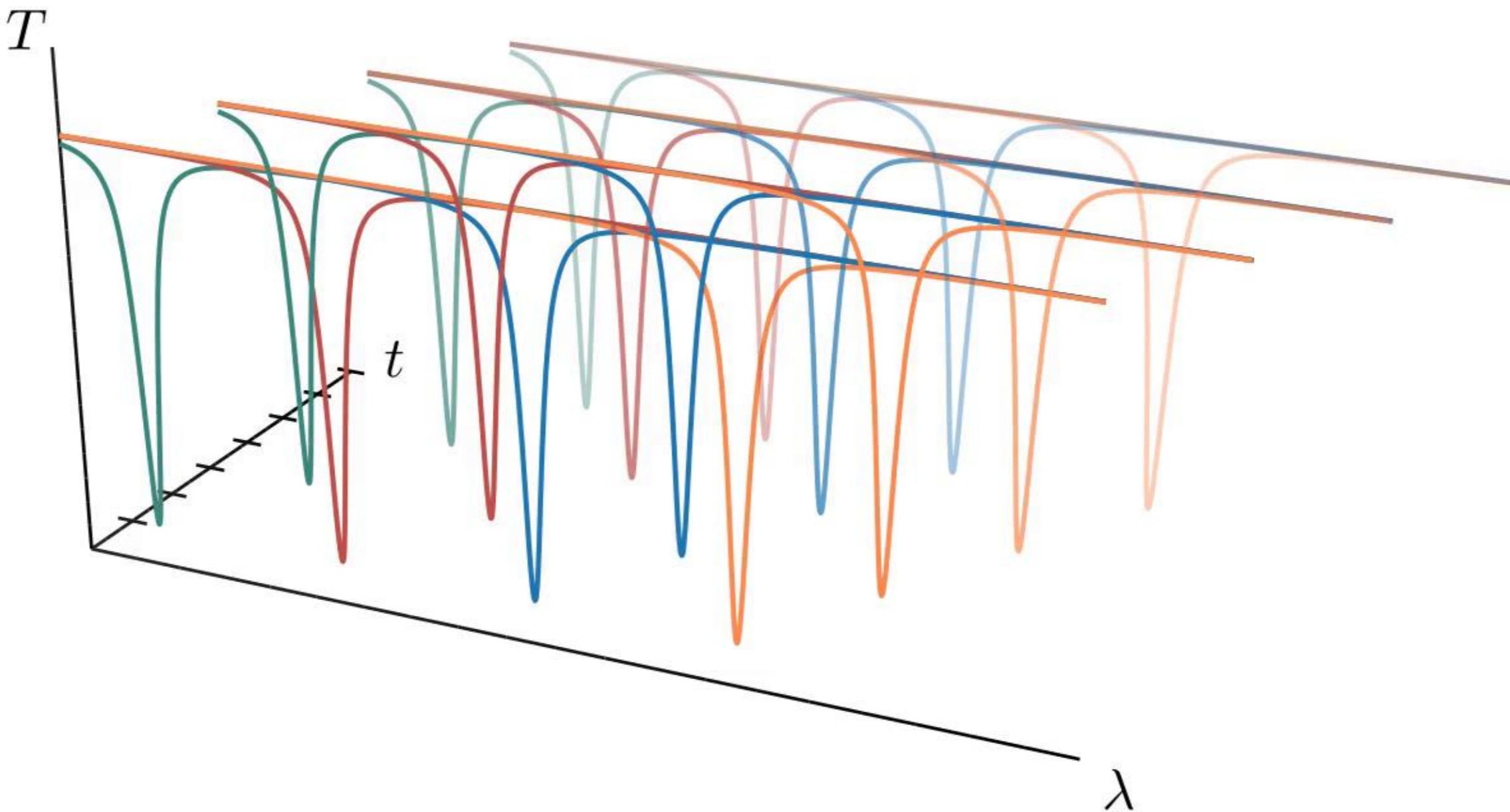
$$\begin{bmatrix}x_1\\x_2\\x_3\\1\end{bmatrix}\cdot \begin{bmatrix}w_1\\w_2\\w_3\\w_4\end{bmatrix}$$

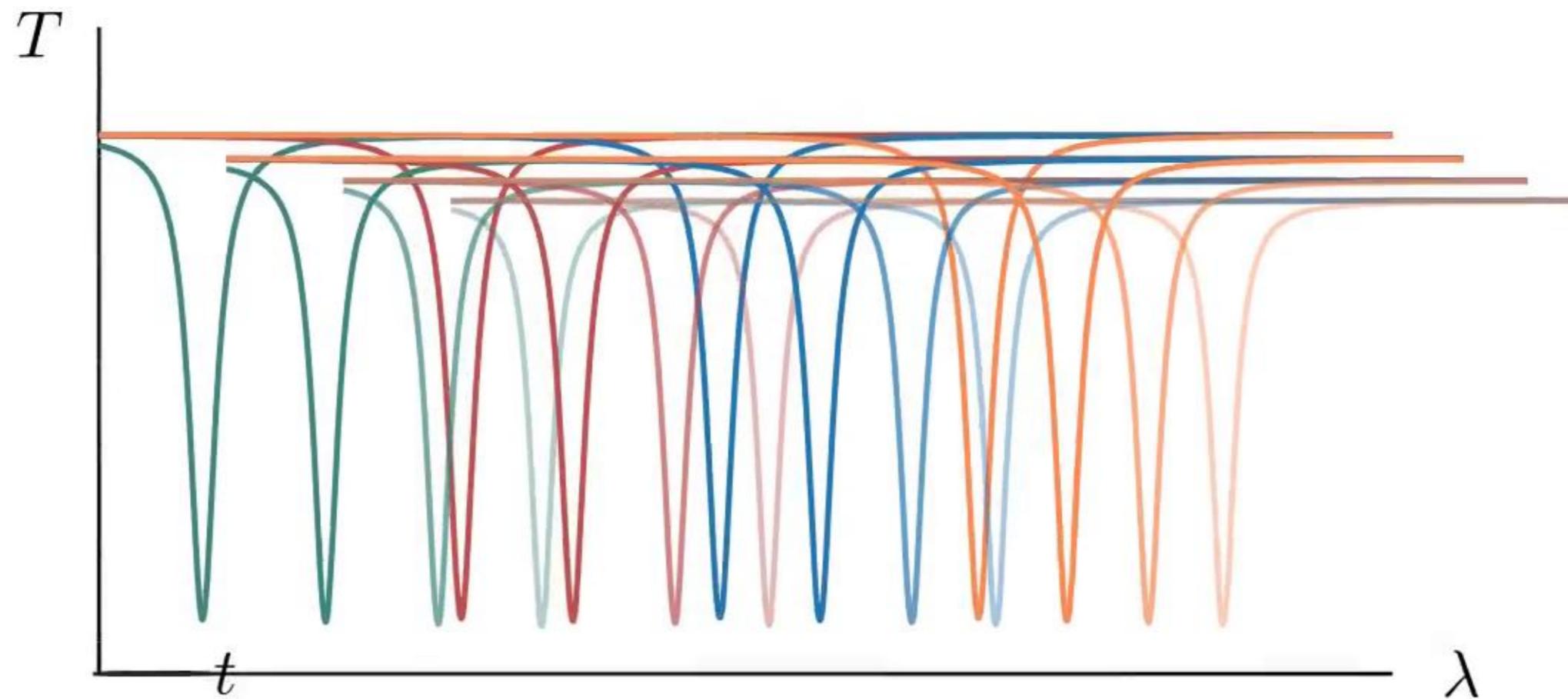
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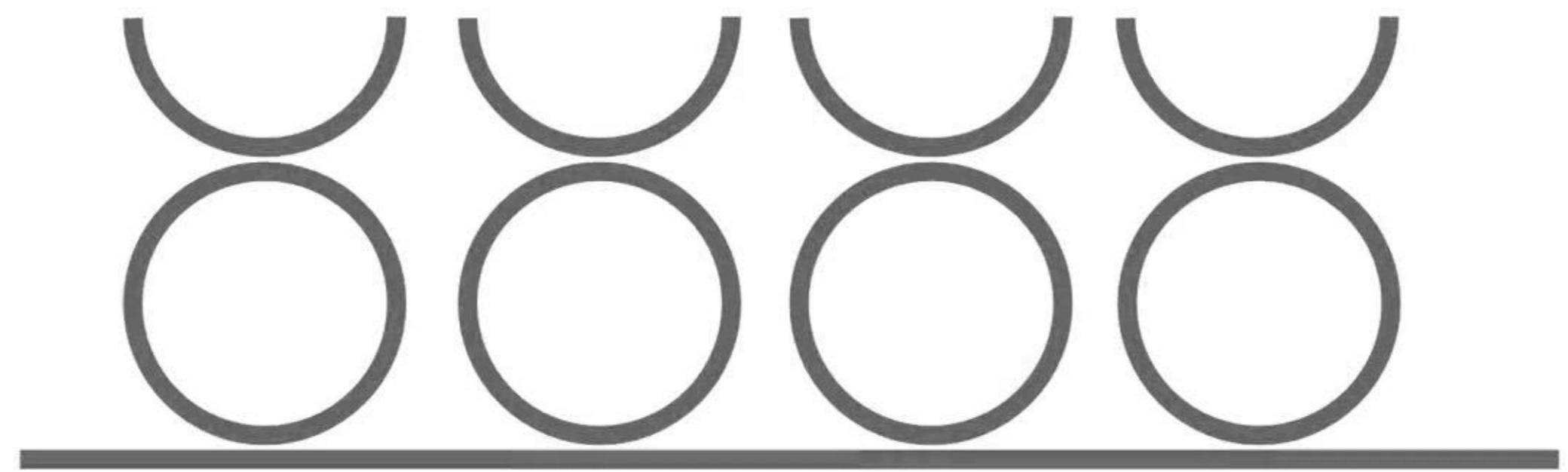
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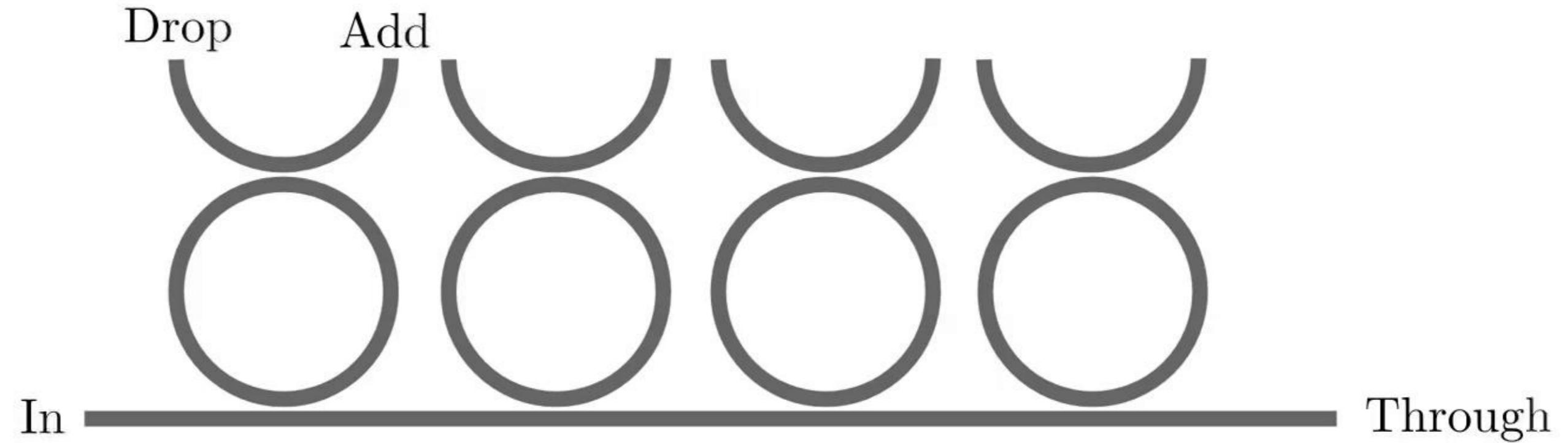


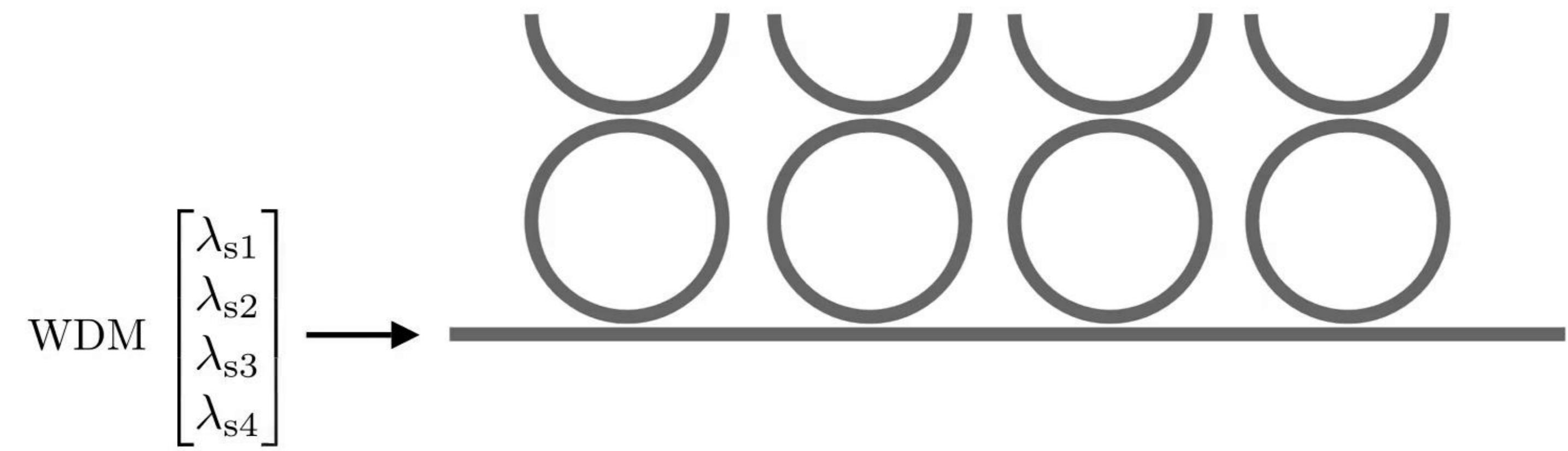


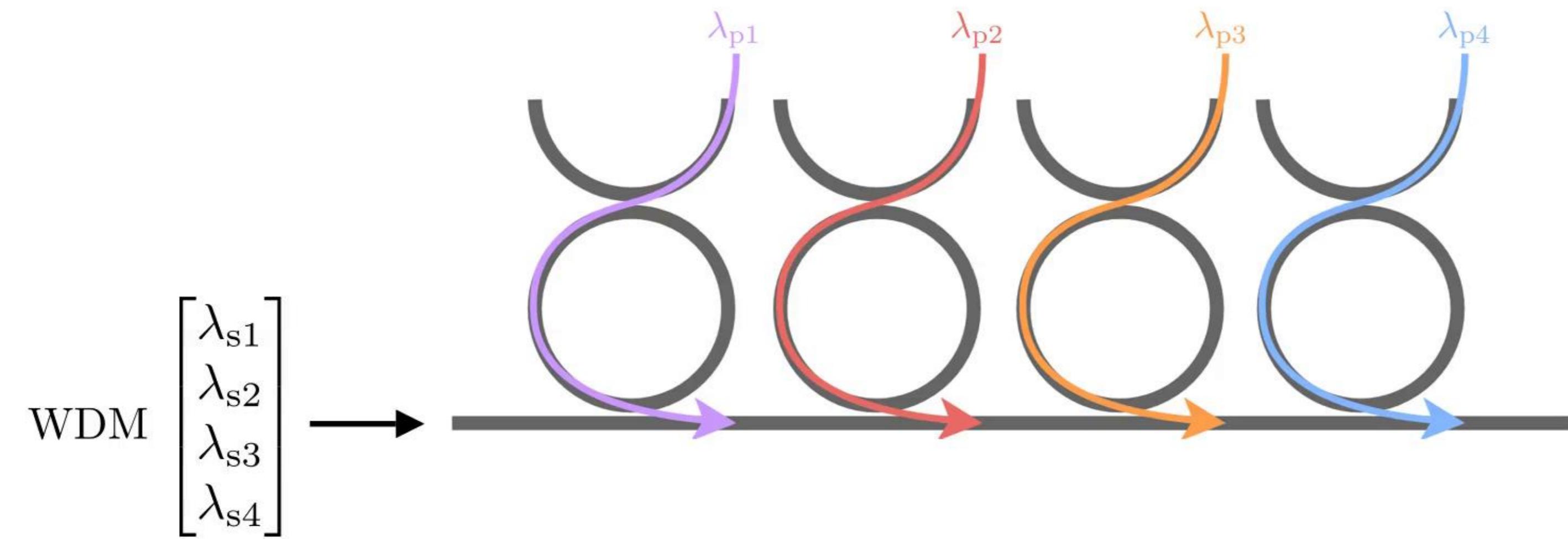


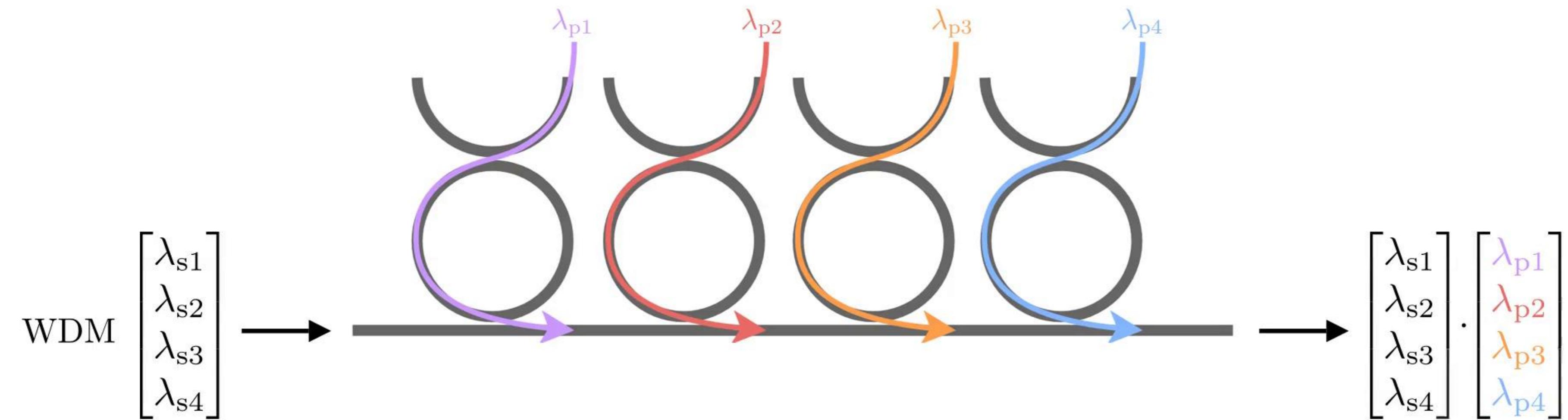












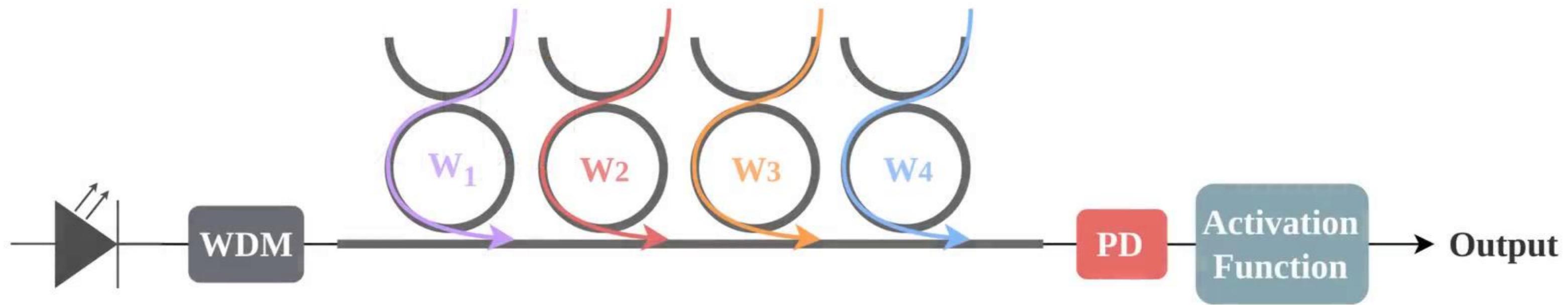
$$\begin{bmatrix} \lambda_{s1} \\ \lambda_{s2} \\ \lambda_{s3} \\ \lambda_{s4} \end{bmatrix} \cdot \begin{bmatrix} \lambda_{p1} \\ \lambda_{p2} \\ \lambda_{p3} \\ \lambda_{p4} \end{bmatrix} = \lambda_{s1}\lambda_{p1} + \lambda_{s2}\lambda_{p2} + \lambda_{s3}\lambda_{p3} + \lambda_{s4}\lambda_{p4}$$

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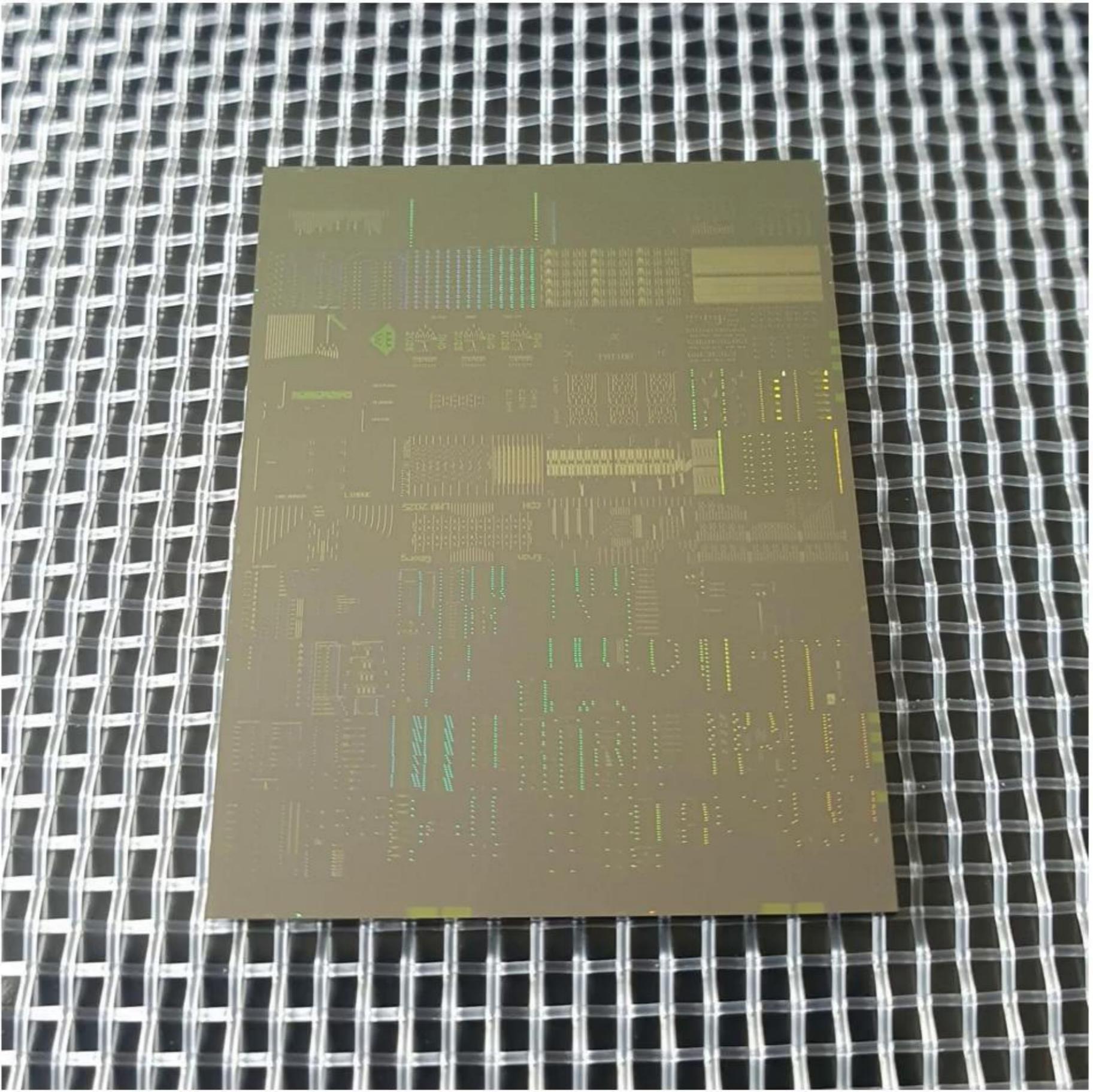
$$\begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ 1 \end{bmatrix} \cdot \begin{bmatrix} w_1 \\ w_2 \\ w_3 \\ w_4 \end{bmatrix} = x_1w_1 + x_2w_2 + x_3w_3 + w_4$$

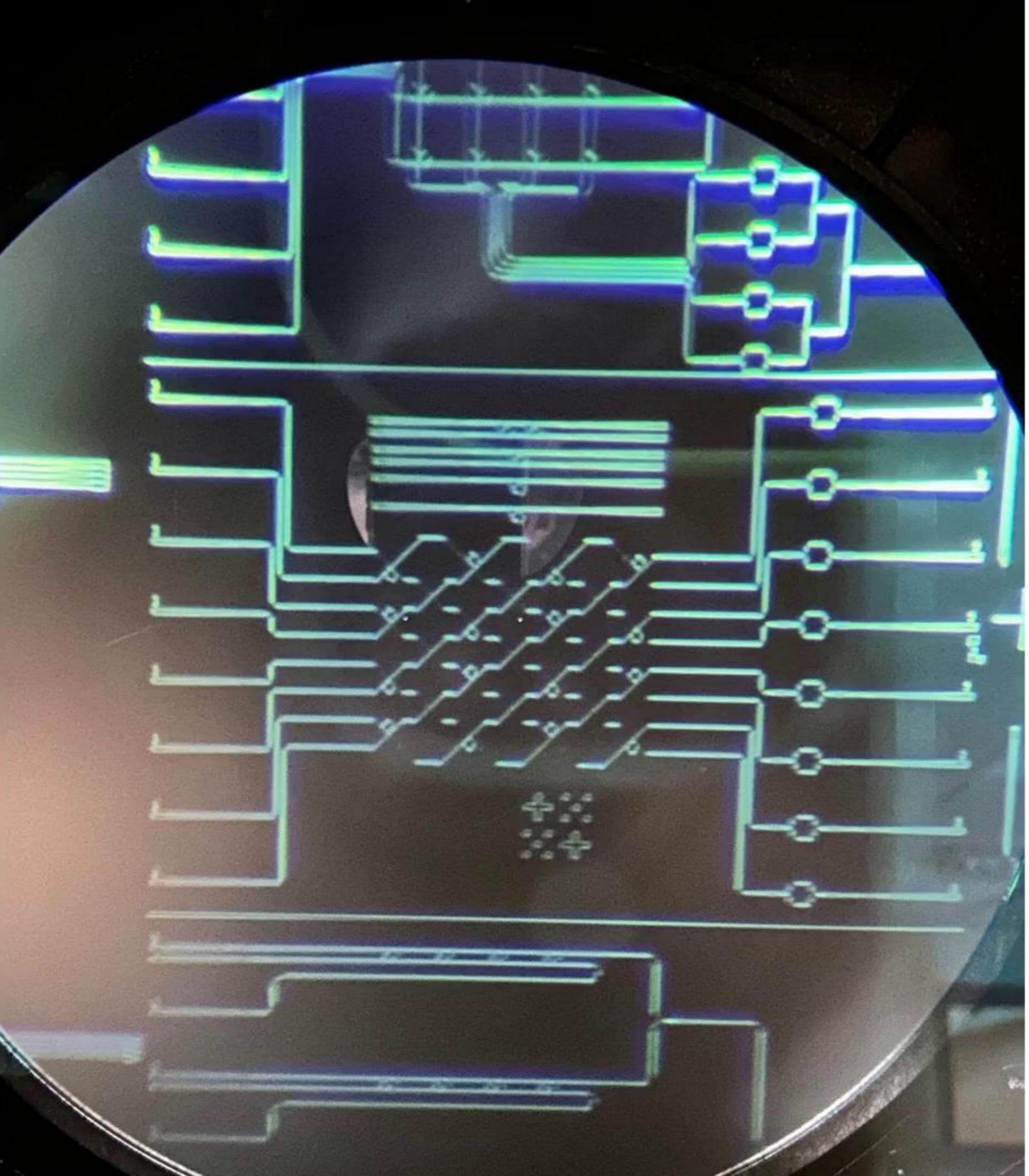
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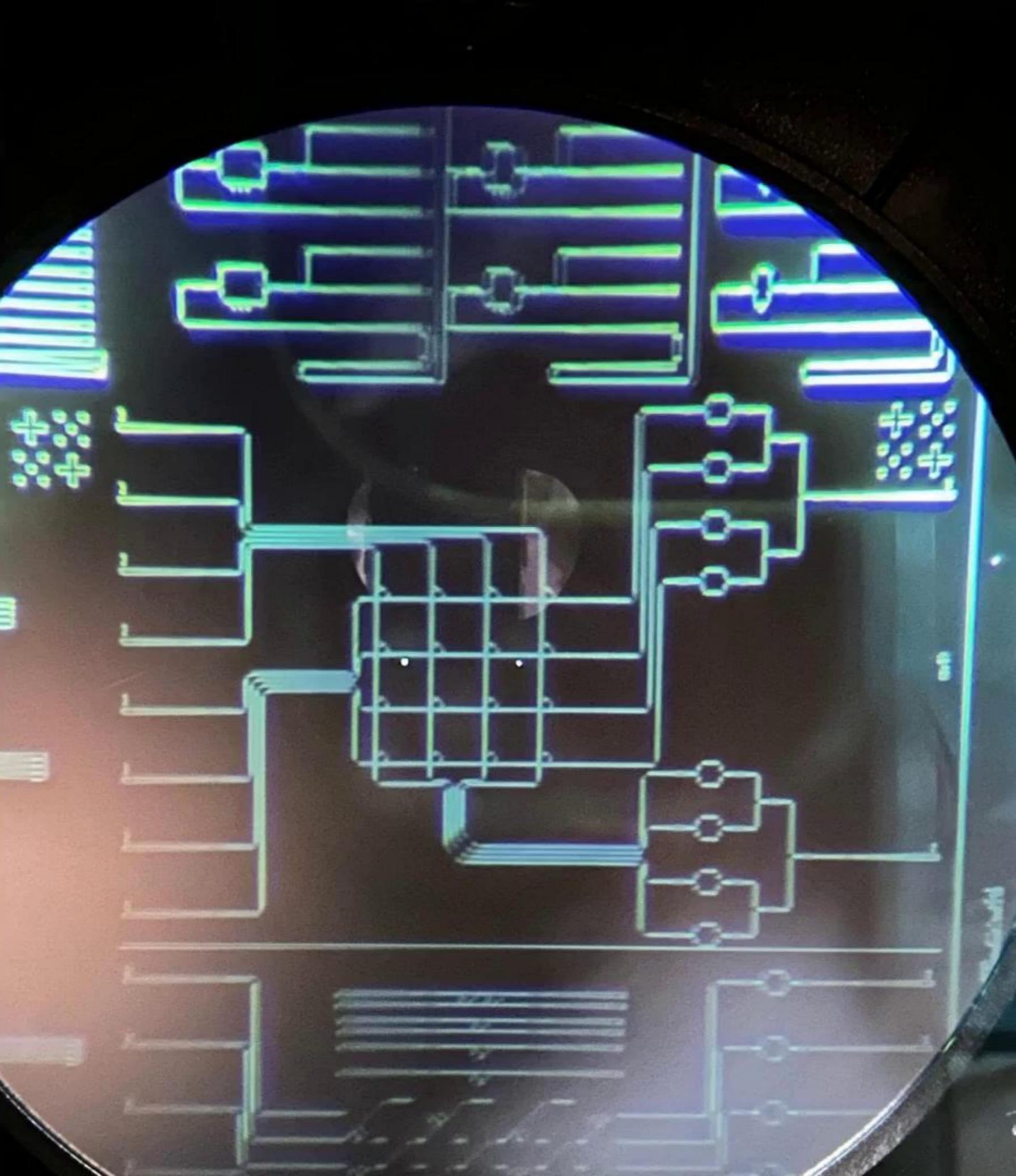
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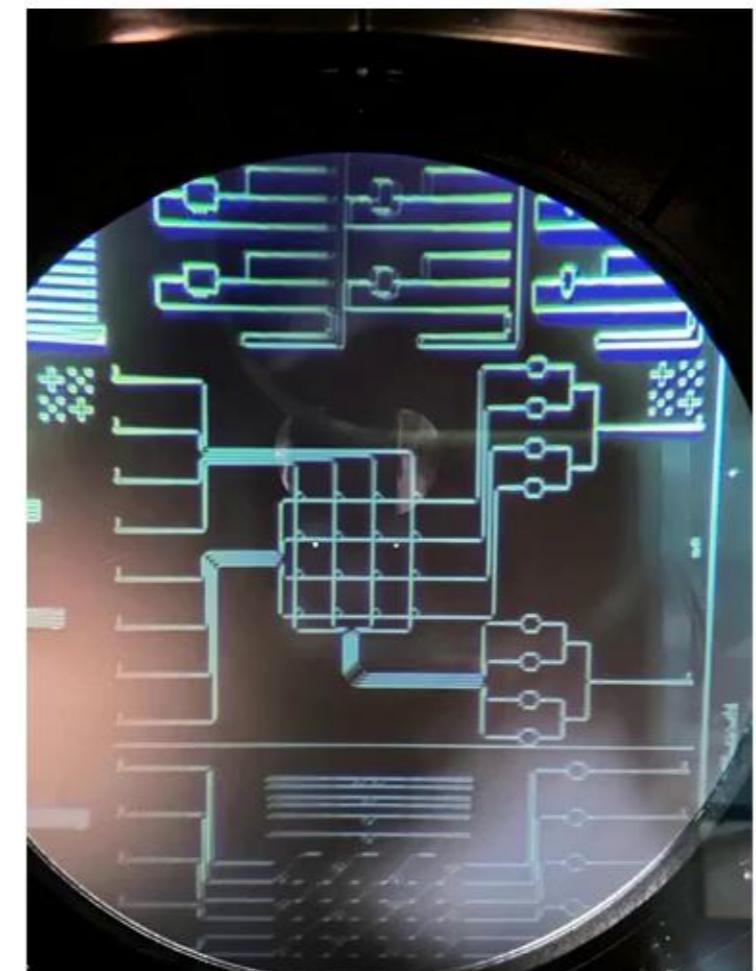
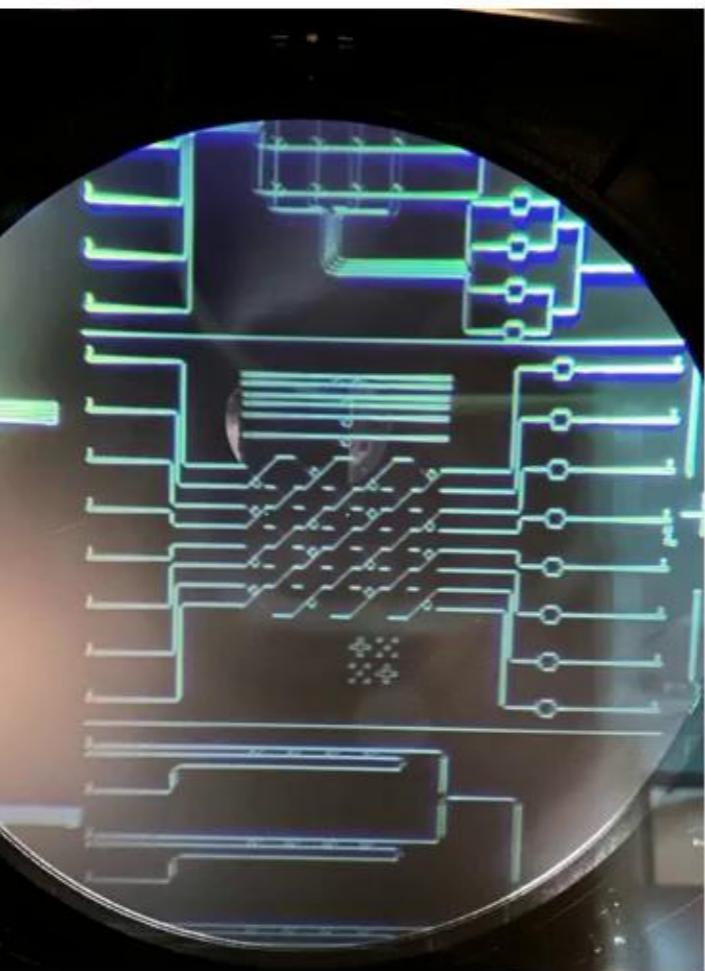
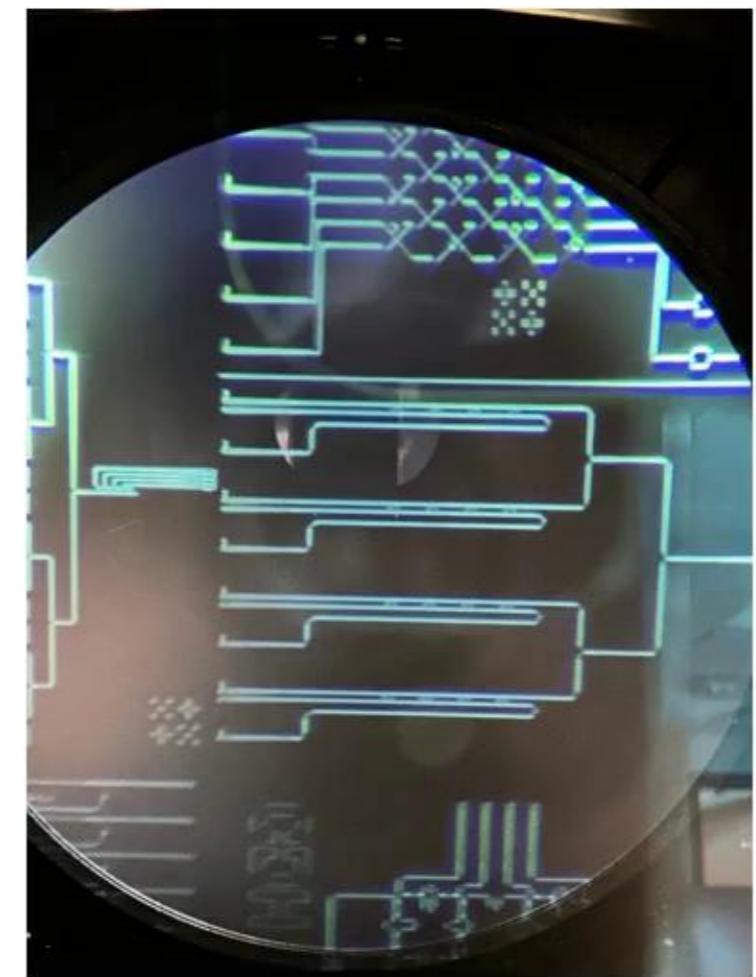


$$\begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ 1 \end{bmatrix} \cdot \begin{bmatrix} w_1 \\ w_2 \\ w_3 \\ w_4 \end{bmatrix} = x_1 w_1 + x_2 w_2 + x_3 w_3 + w_4$$









Thank You

Steven Parsonage

Farah Comis

Alfonso Ruocco