

Polarimetry for DM (Pseudo)Scalar Search

Qazal Rokn

Max Planck Institute for Gravitational Physics/Leibniz Universität Hannover

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- Baryonic dark matter mostly ruled out by micro-lensing
- Non-baryonic dark matter candidates:
 - WIMPs
 - Axion
 - Scalar field
 - ...



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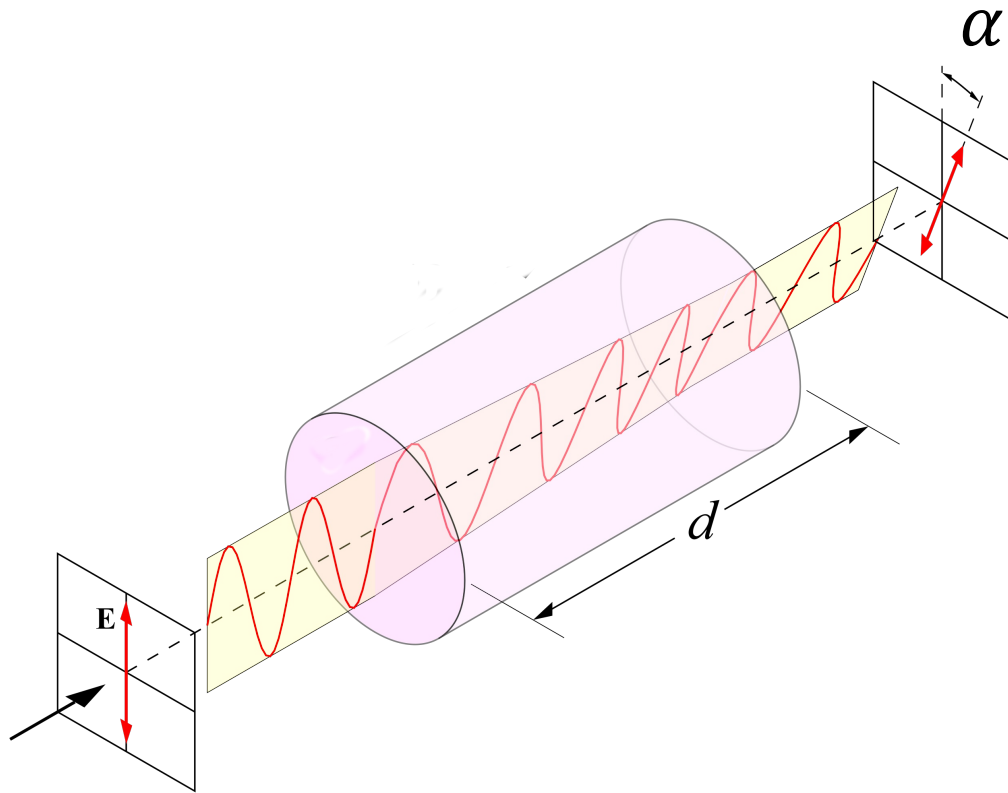
- ...

$$\left. \begin{array}{l} \text{Axion} \\ \text{Scalar field} \\ \dots \end{array} \right\} \phi(t, \vec{r}) = \left[\frac{\hbar \sqrt{2} \rho_{\text{local}}}{m_{\phi} c} \right] \cos \left(\omega_{\phi} t - \vec{k}_{\phi} \cdot \vec{r} \right)$$



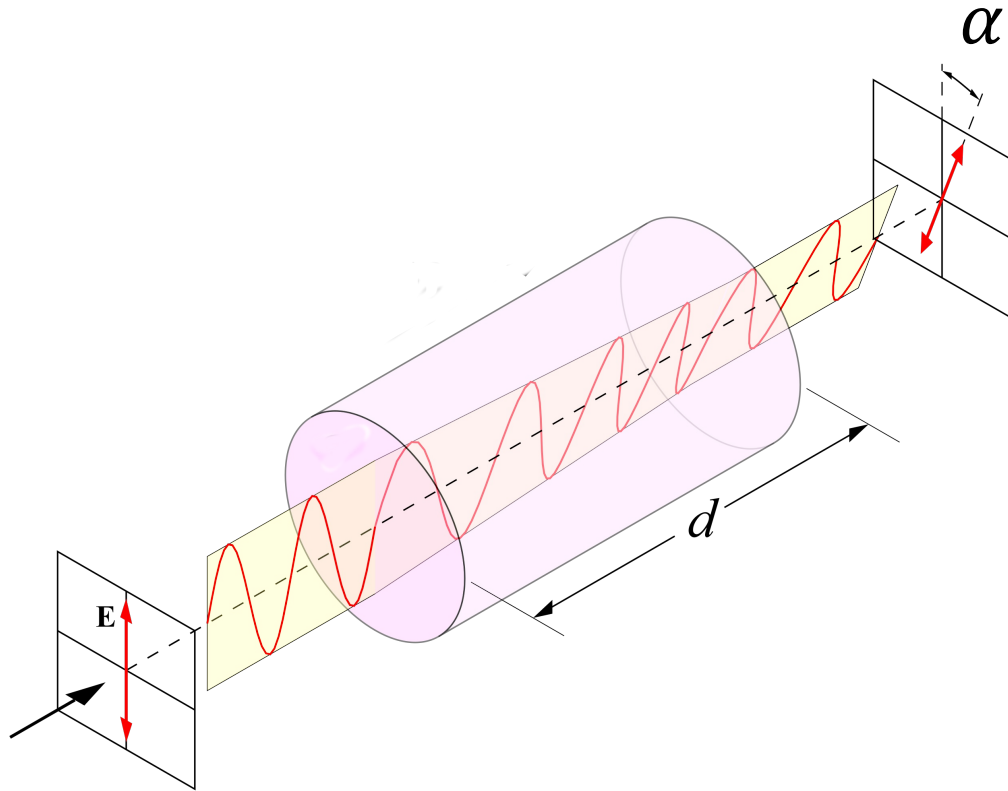
Axion

Axion effect on light

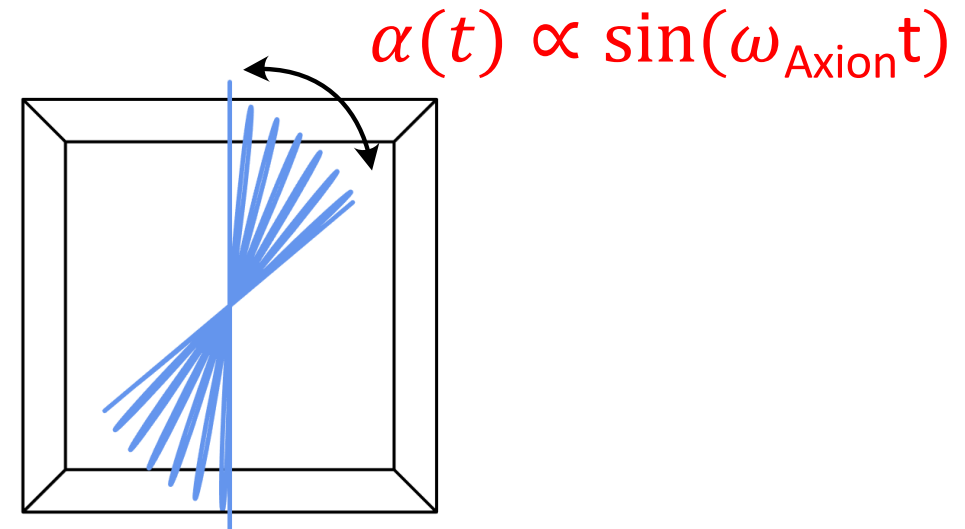


- Axion rotates the polarization of linearly polarized light

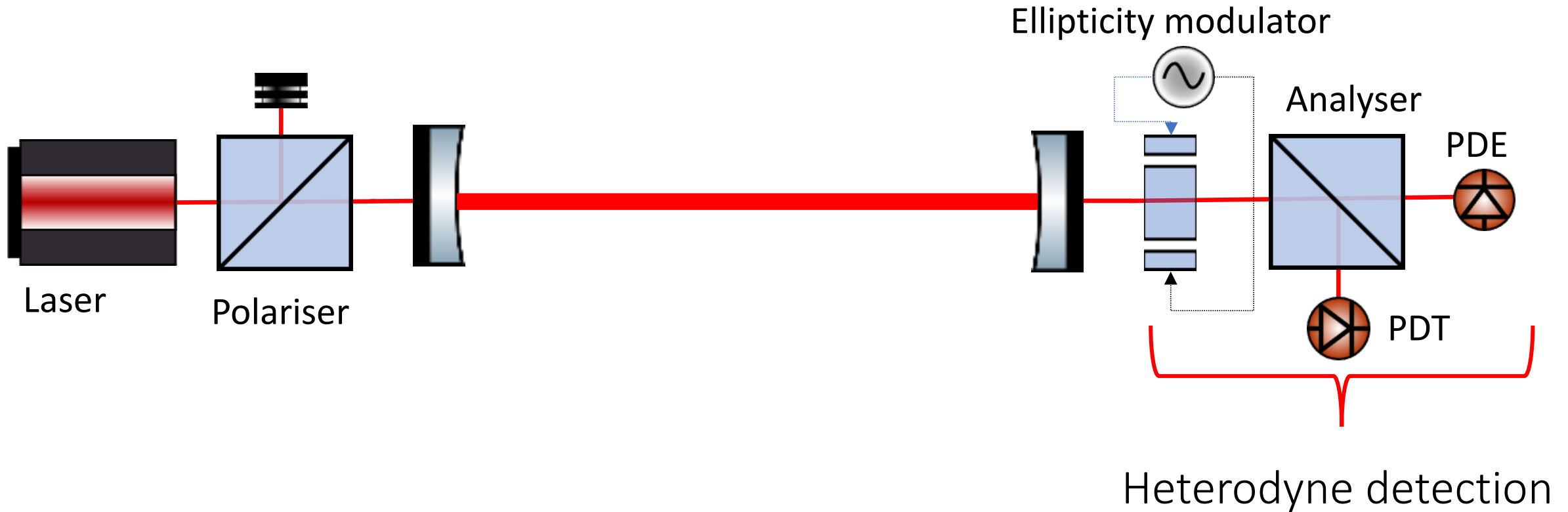
Axion effect on light



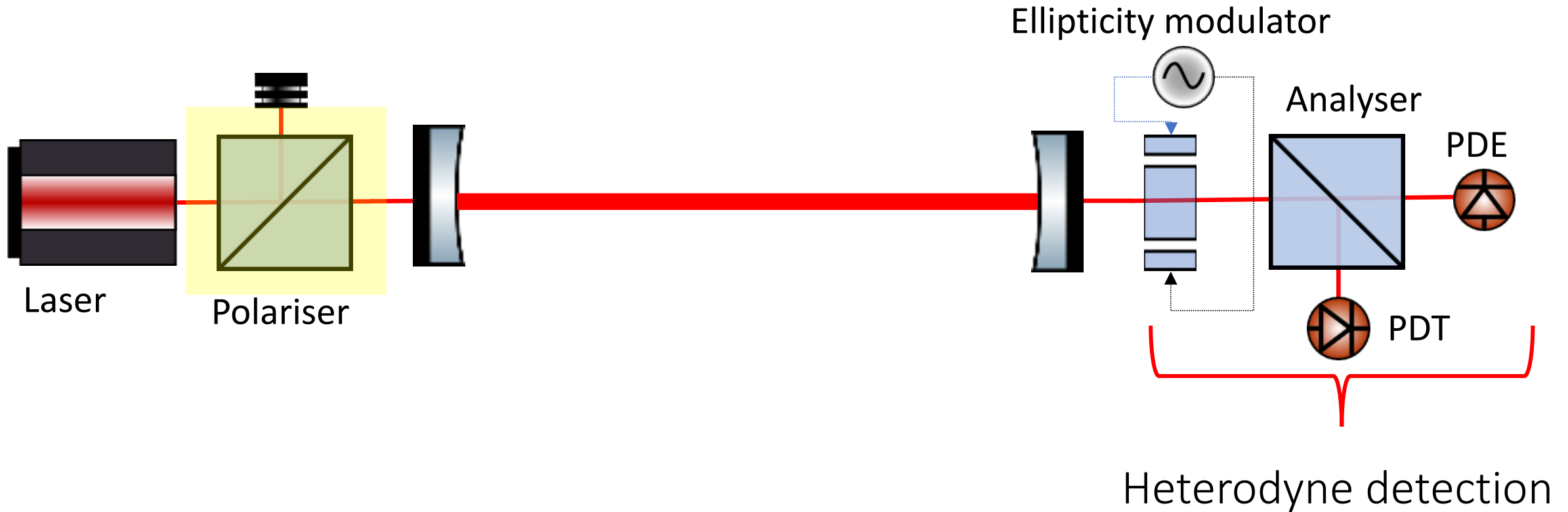
- Axion rotates the polarization of linearly polarized light
- Angle of rotation oscillates with the frequency of Axion field



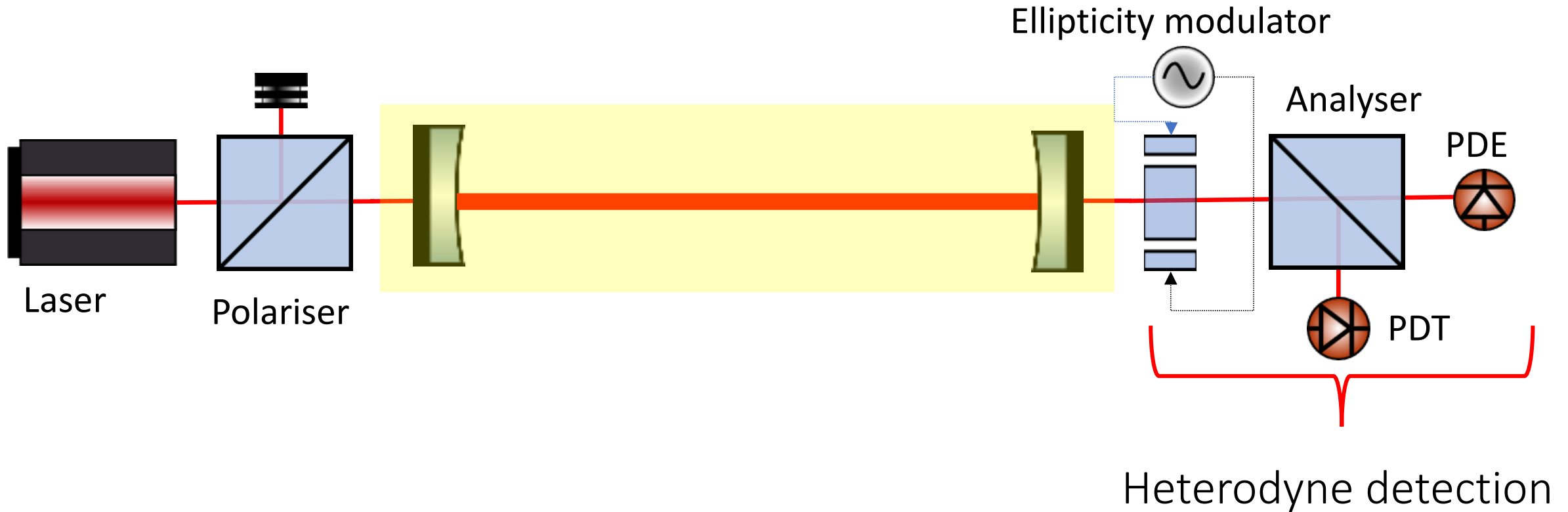
Proposed set up for Axion detection



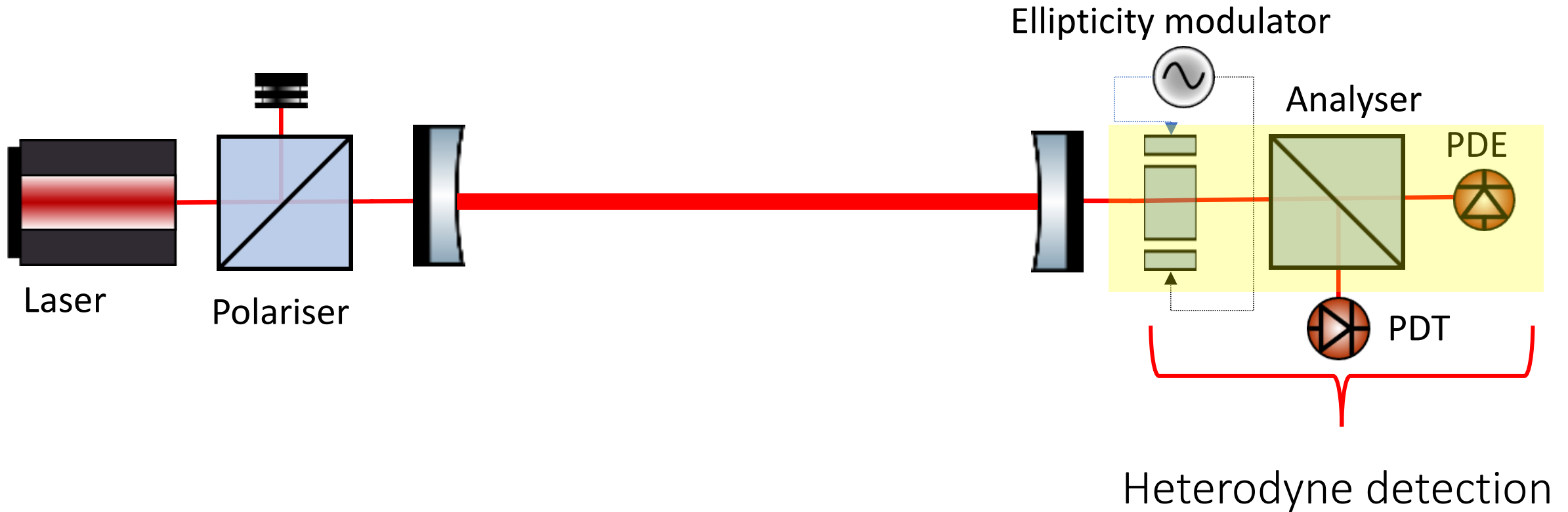
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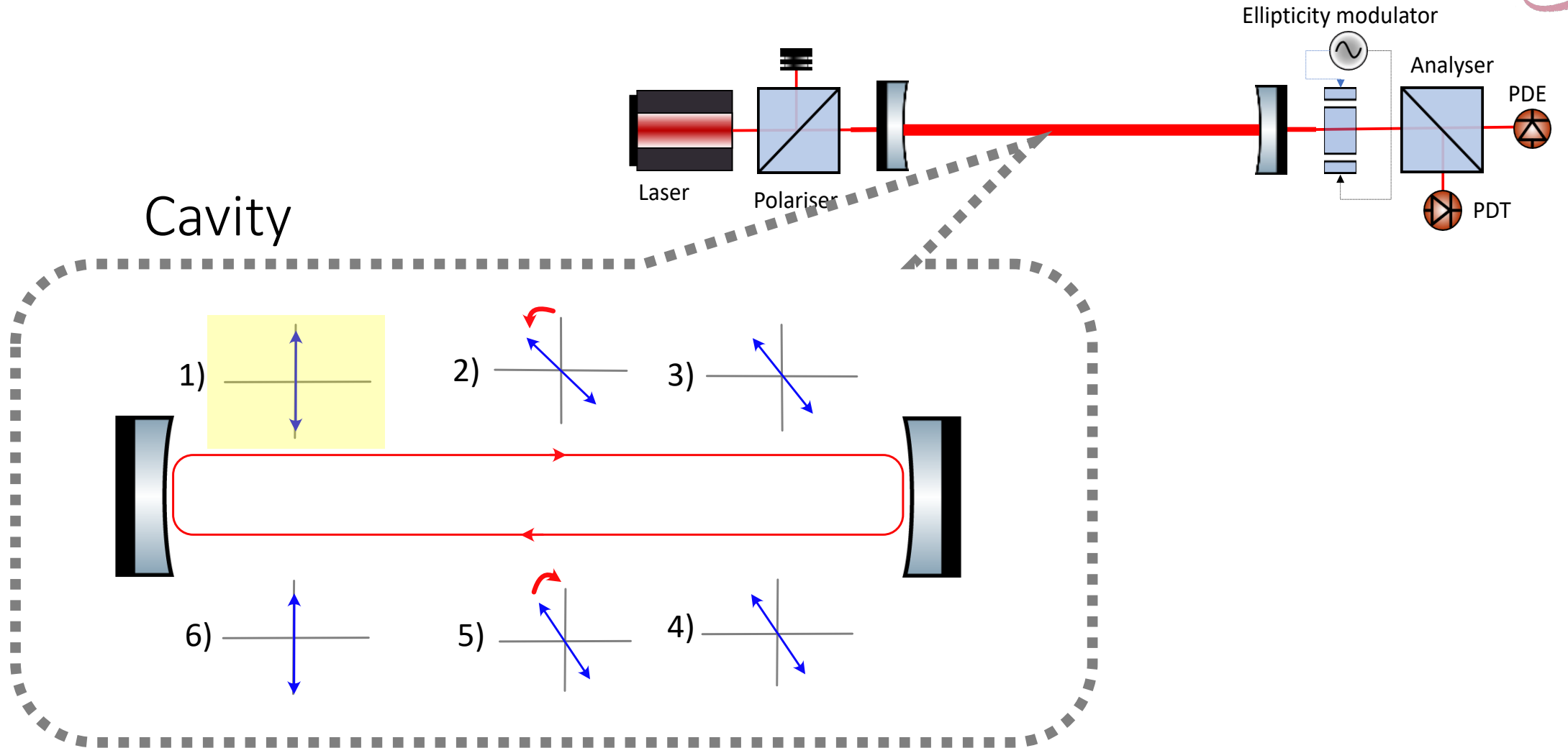
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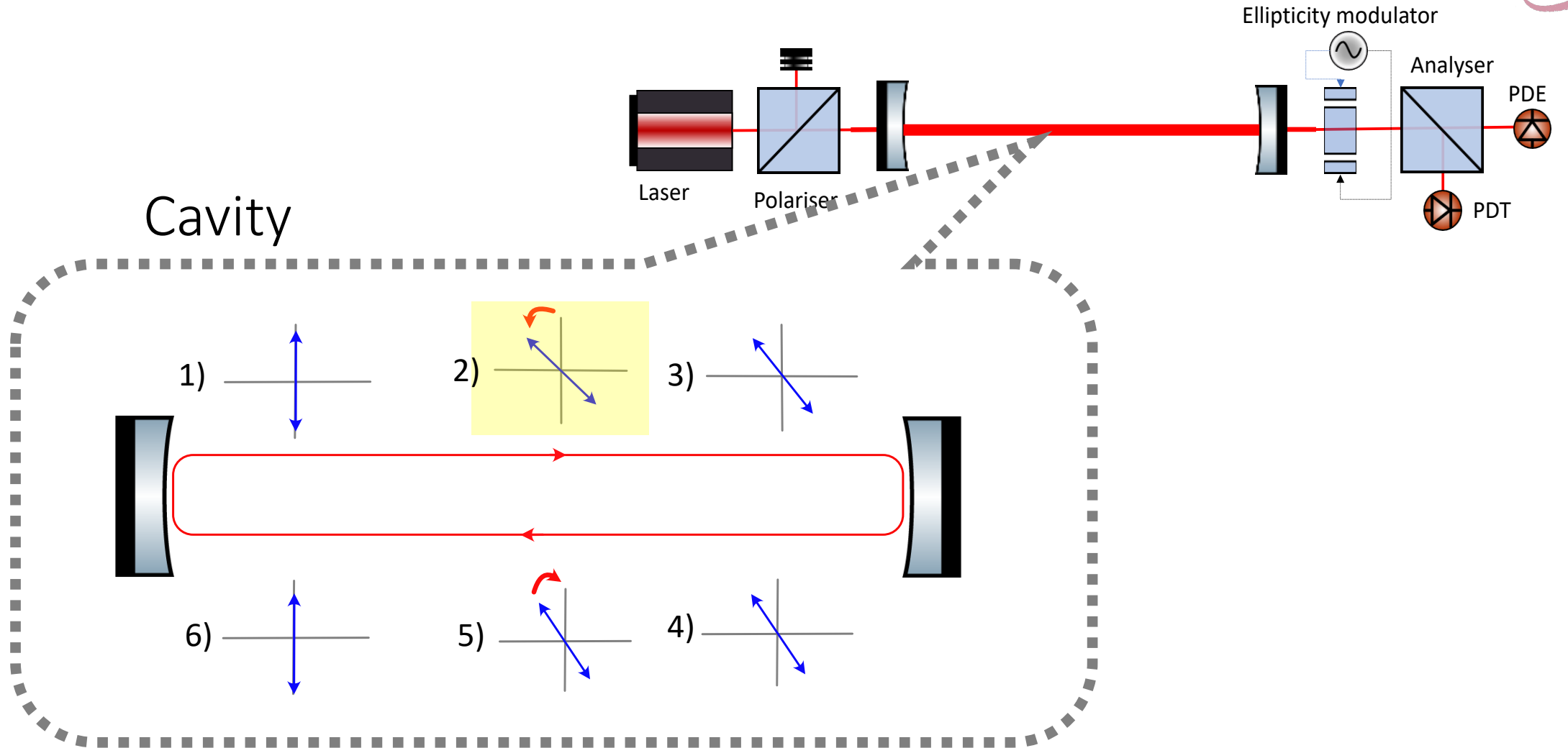
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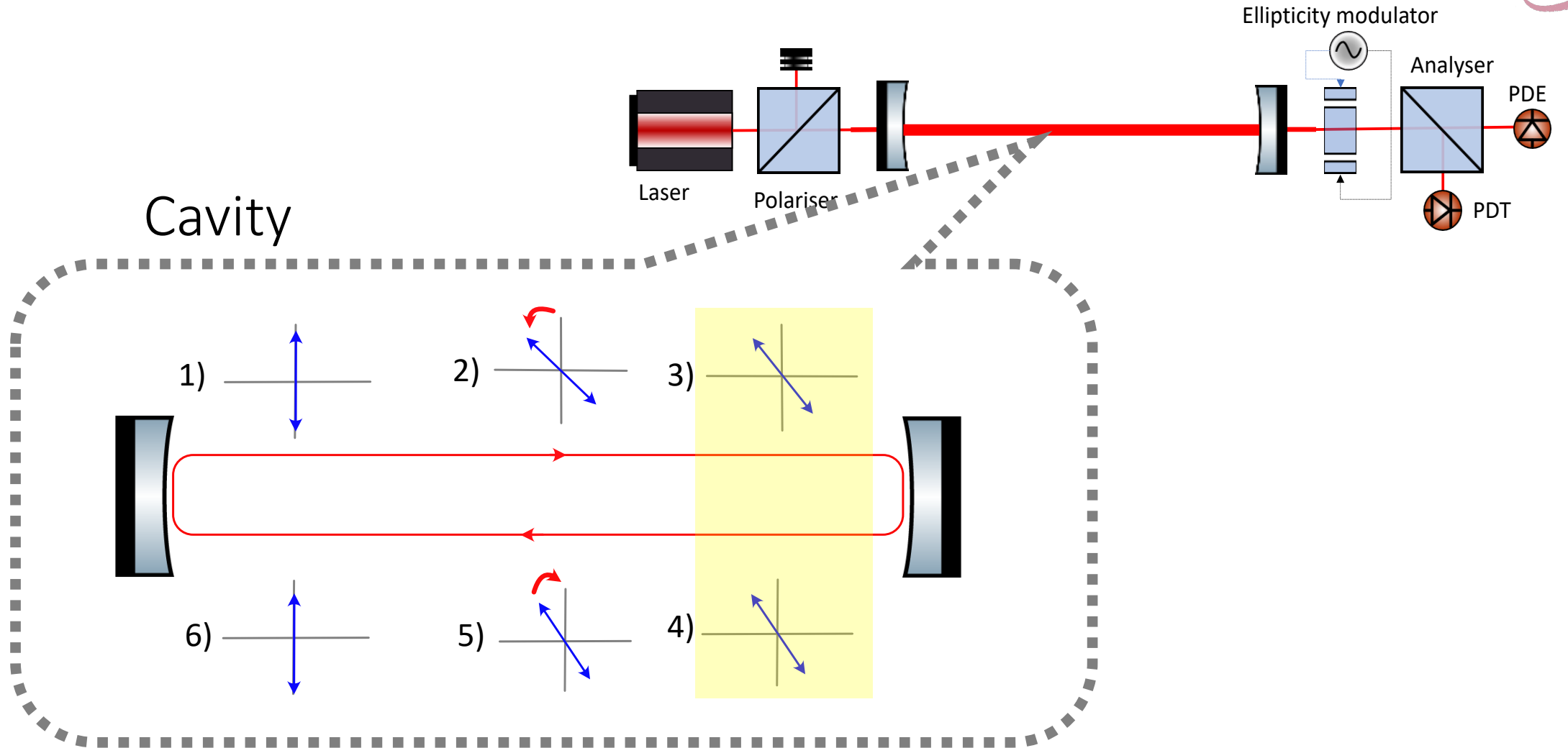
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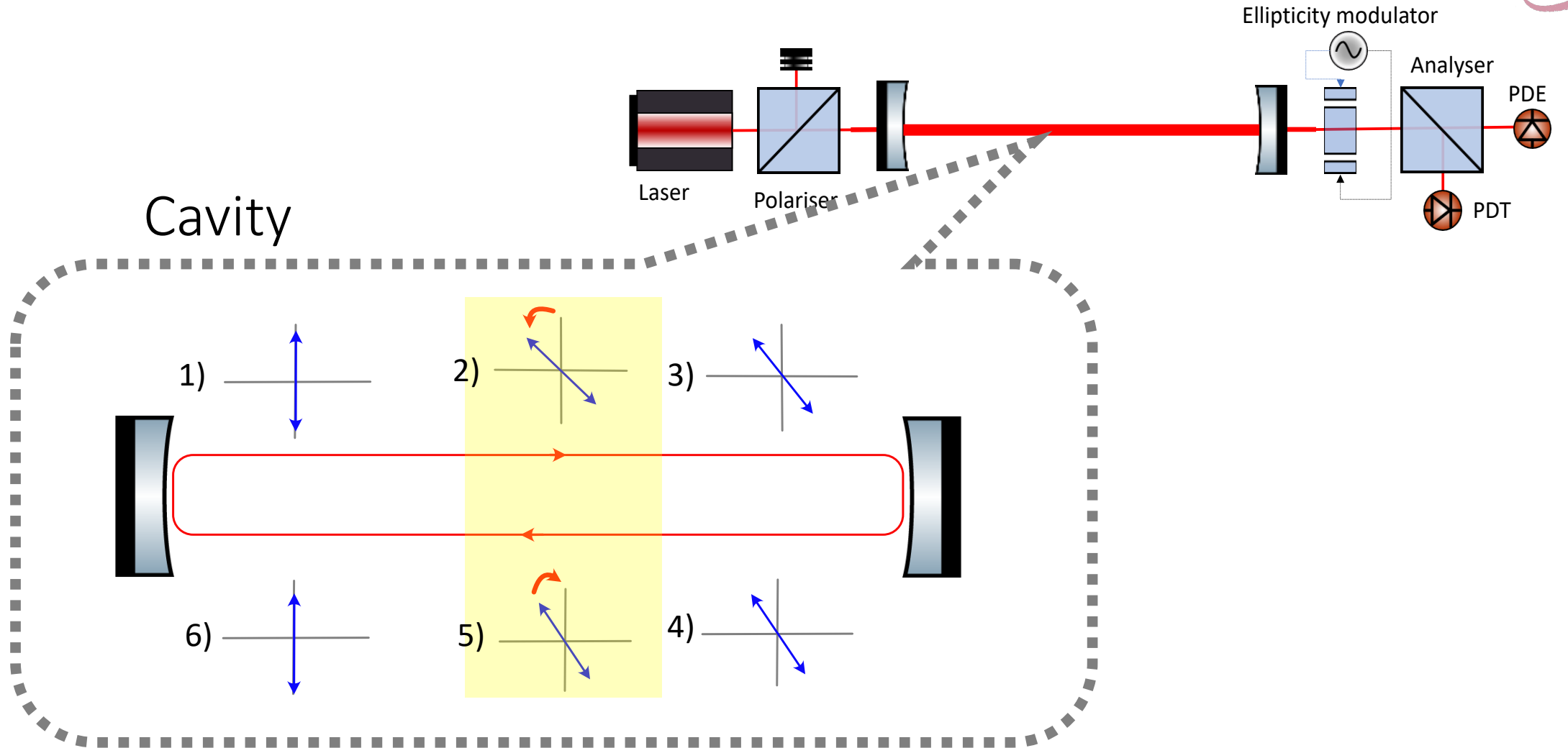
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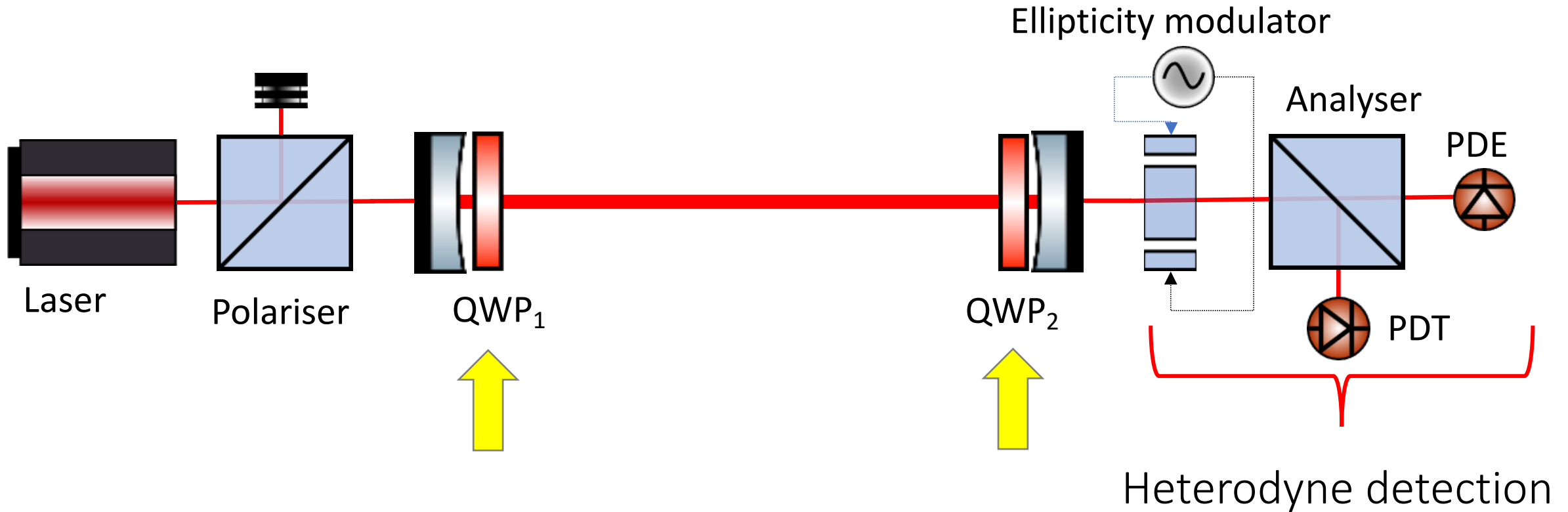
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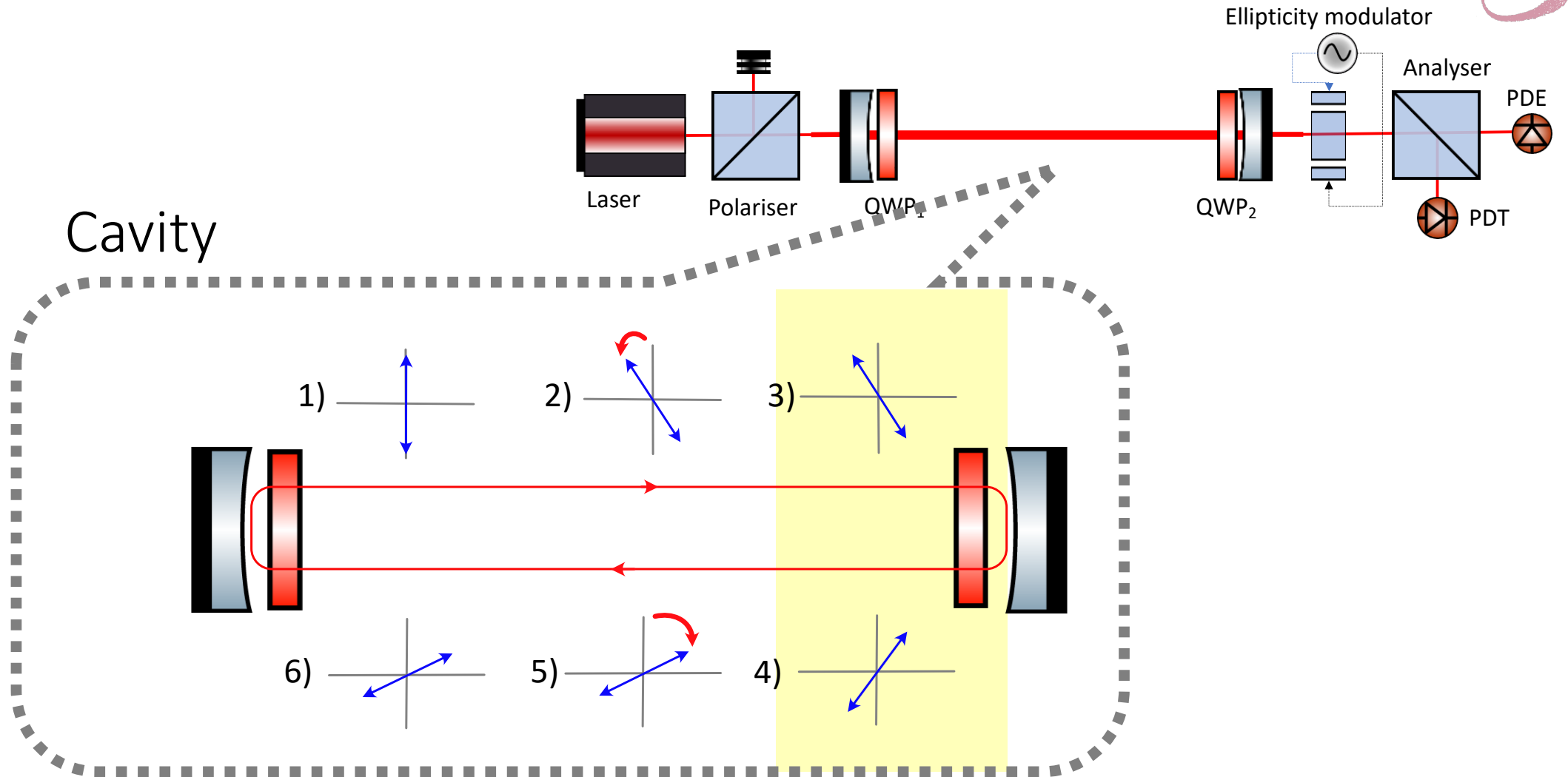
Proposed set up for Axion detection



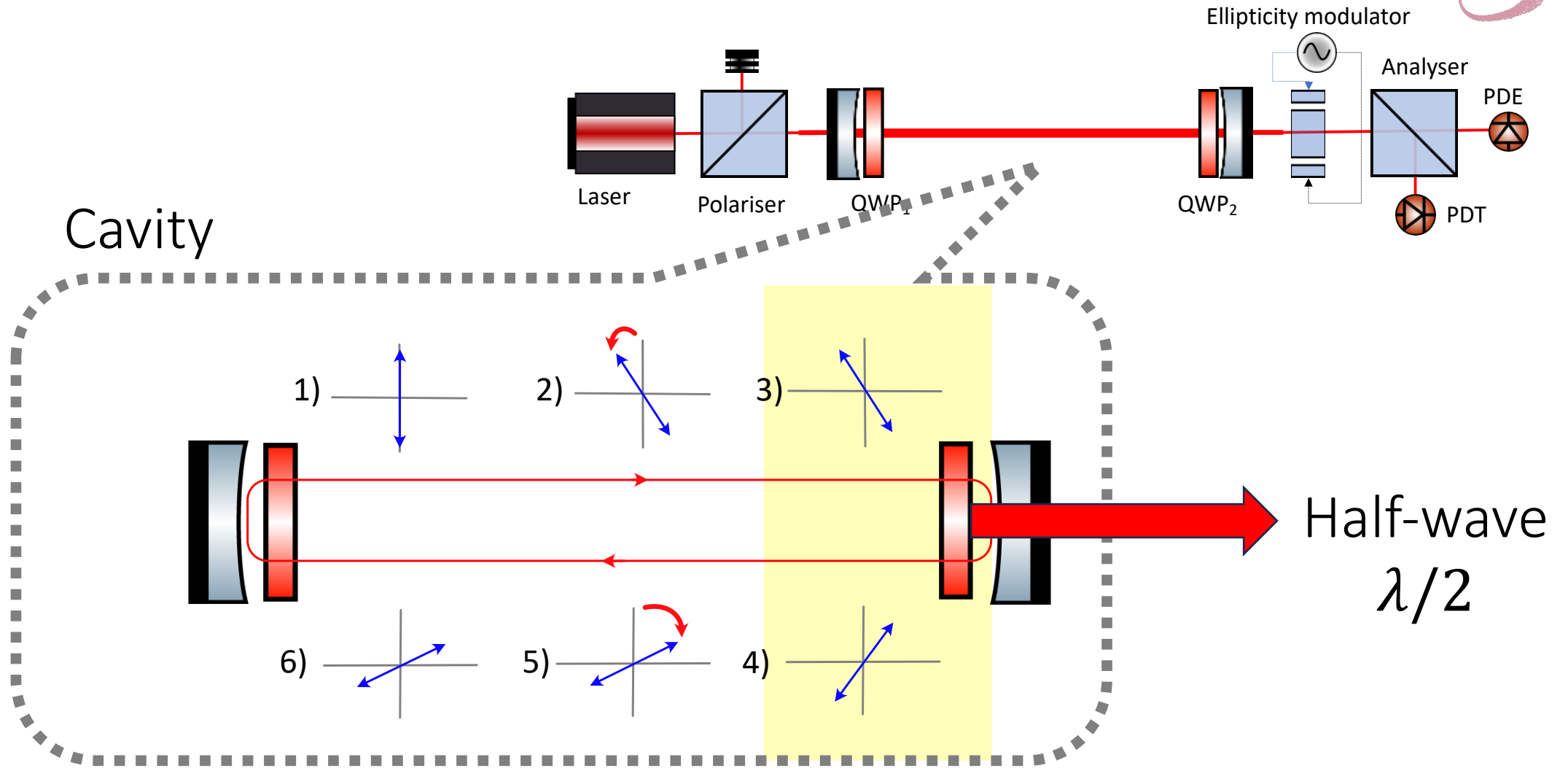
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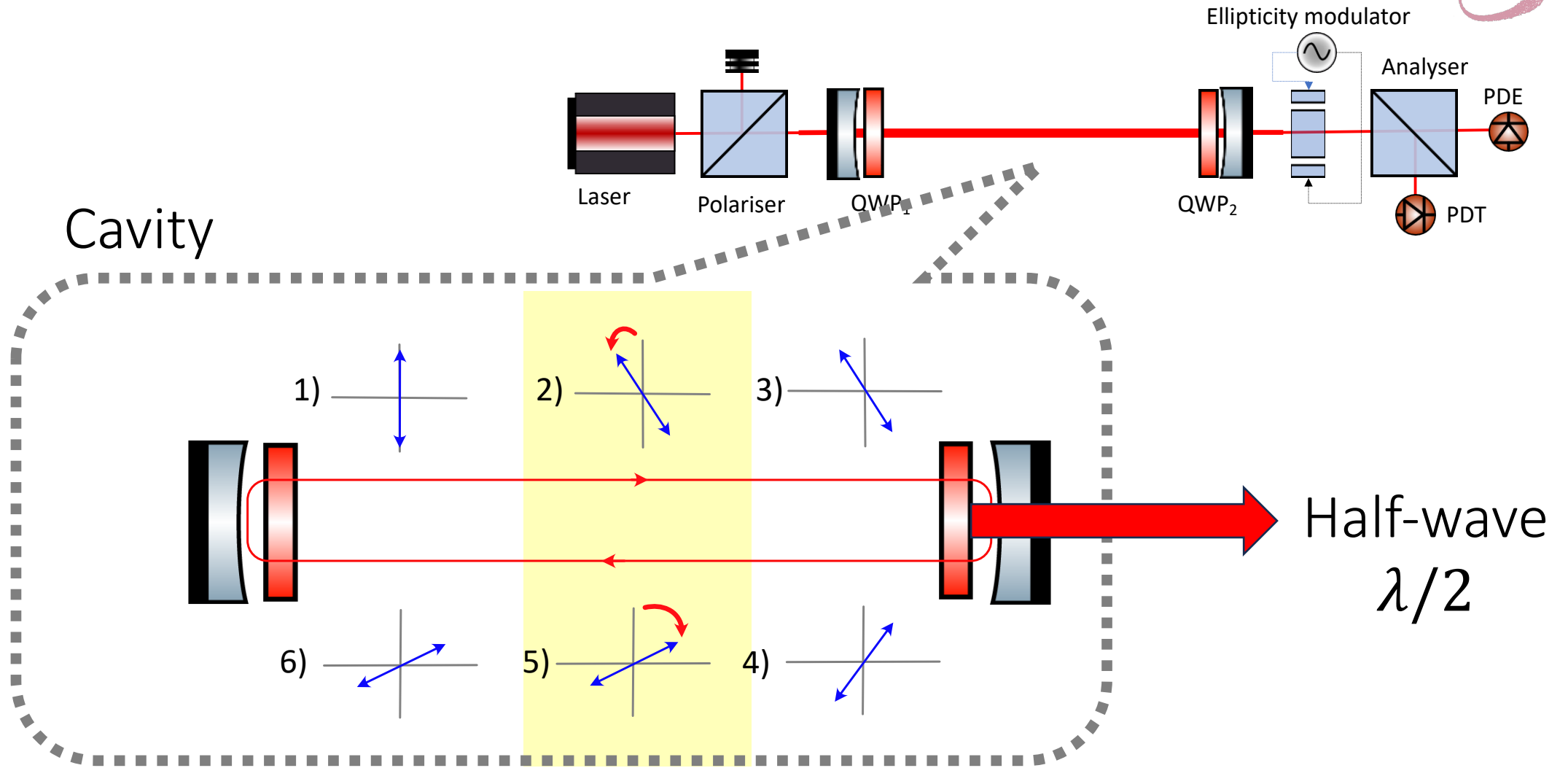
Proposed set up for Axion detection



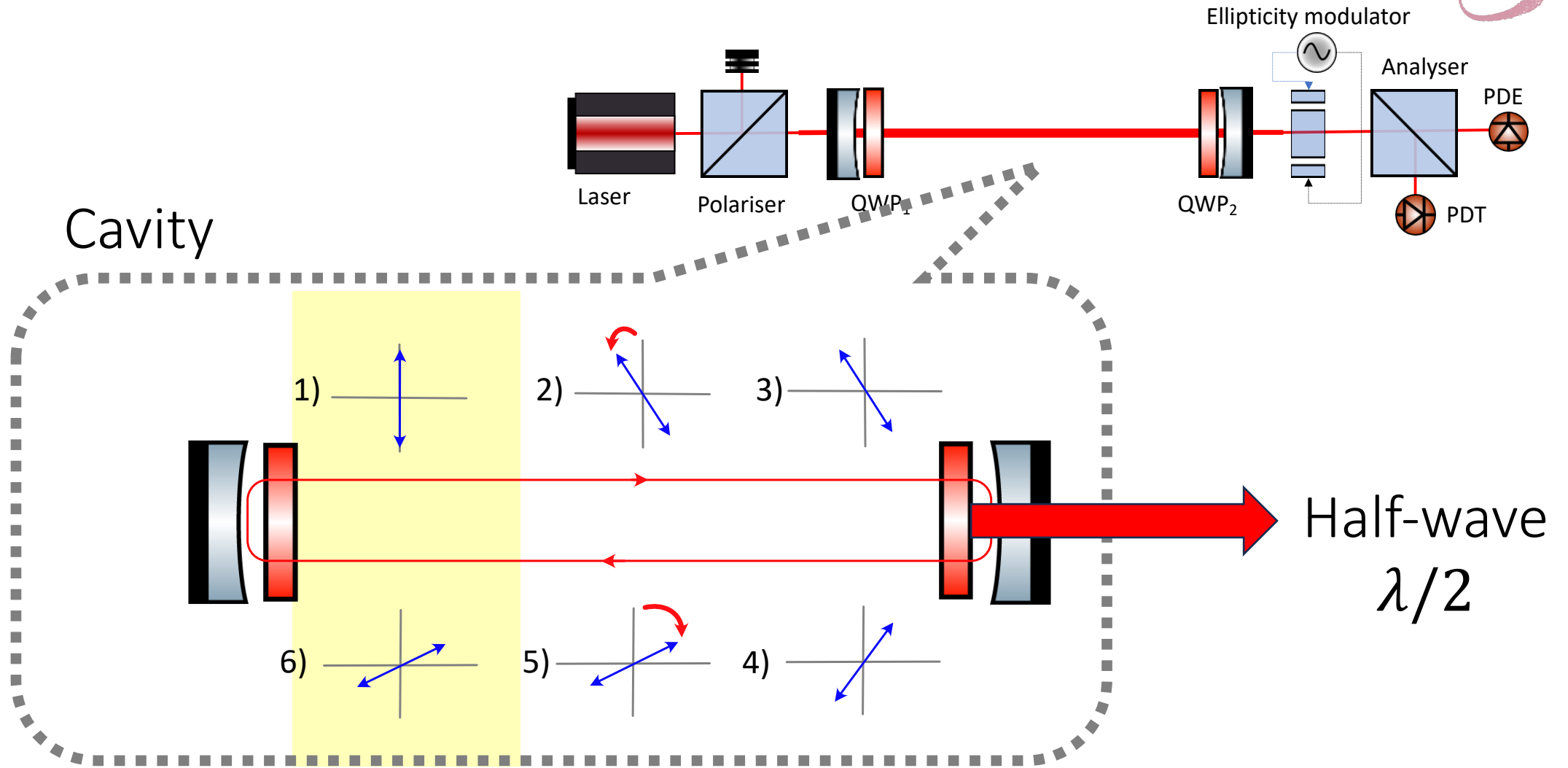
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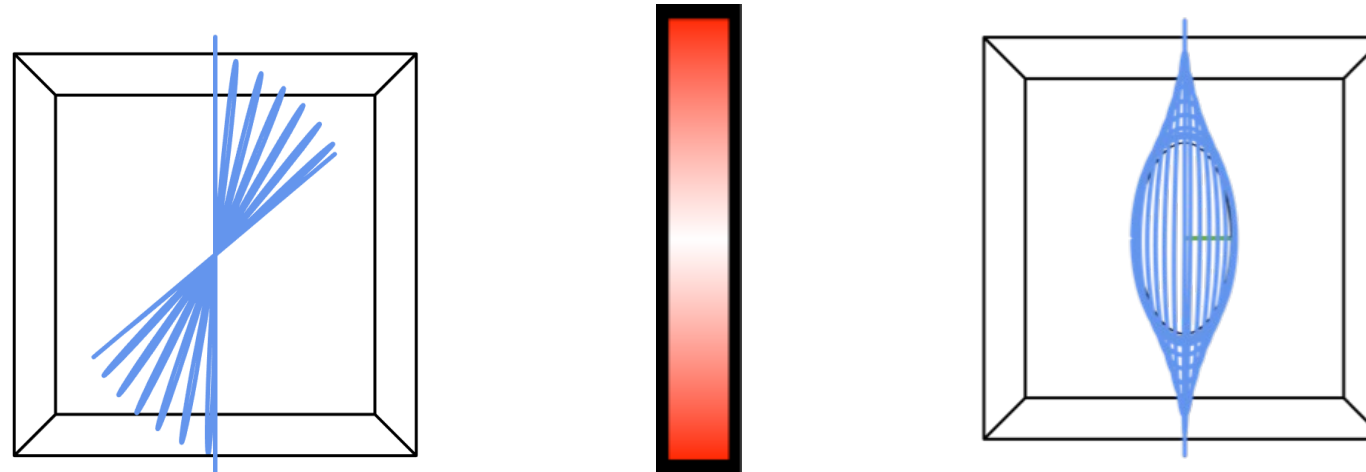
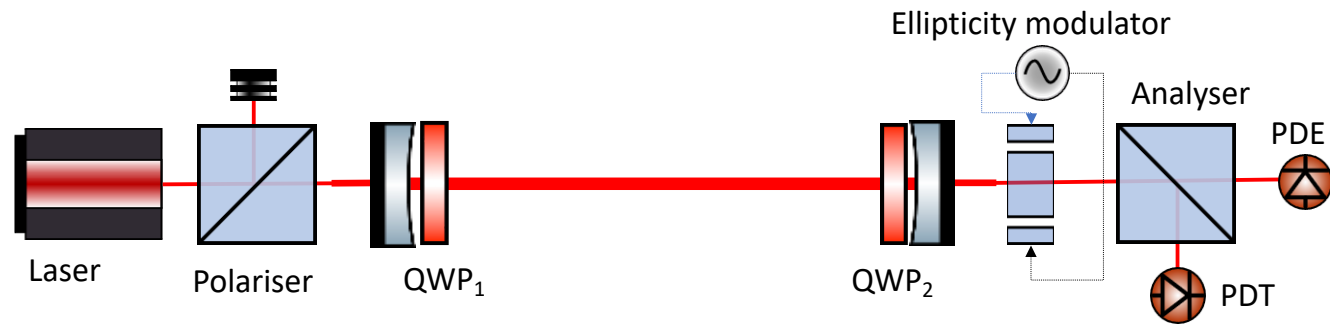
Proposed set up for Axion detection



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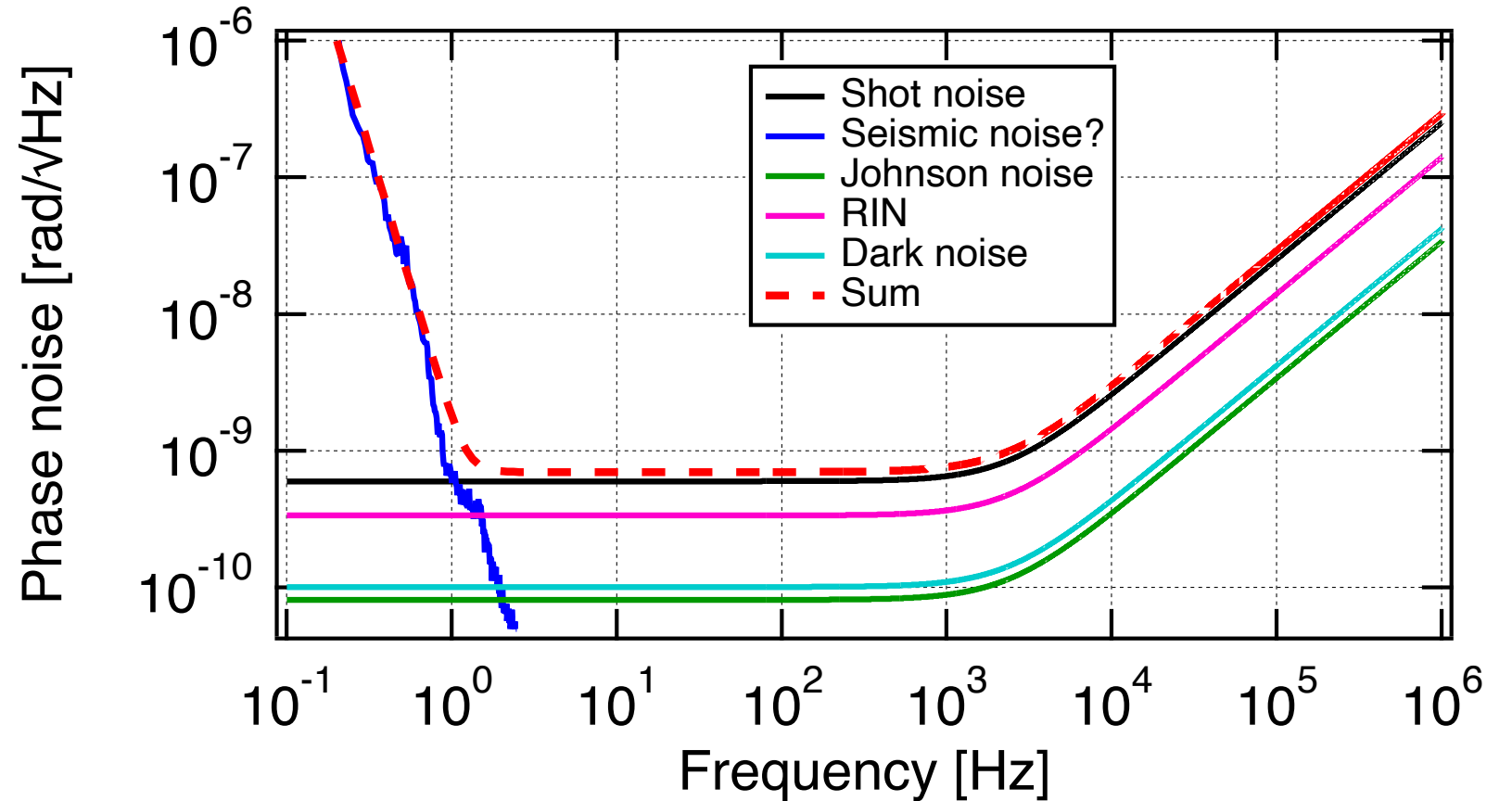


Proposed set up for Axion detection





- Shot noise
- Seismic noise
- RIN noise
- Dark noise
- Thermal noise

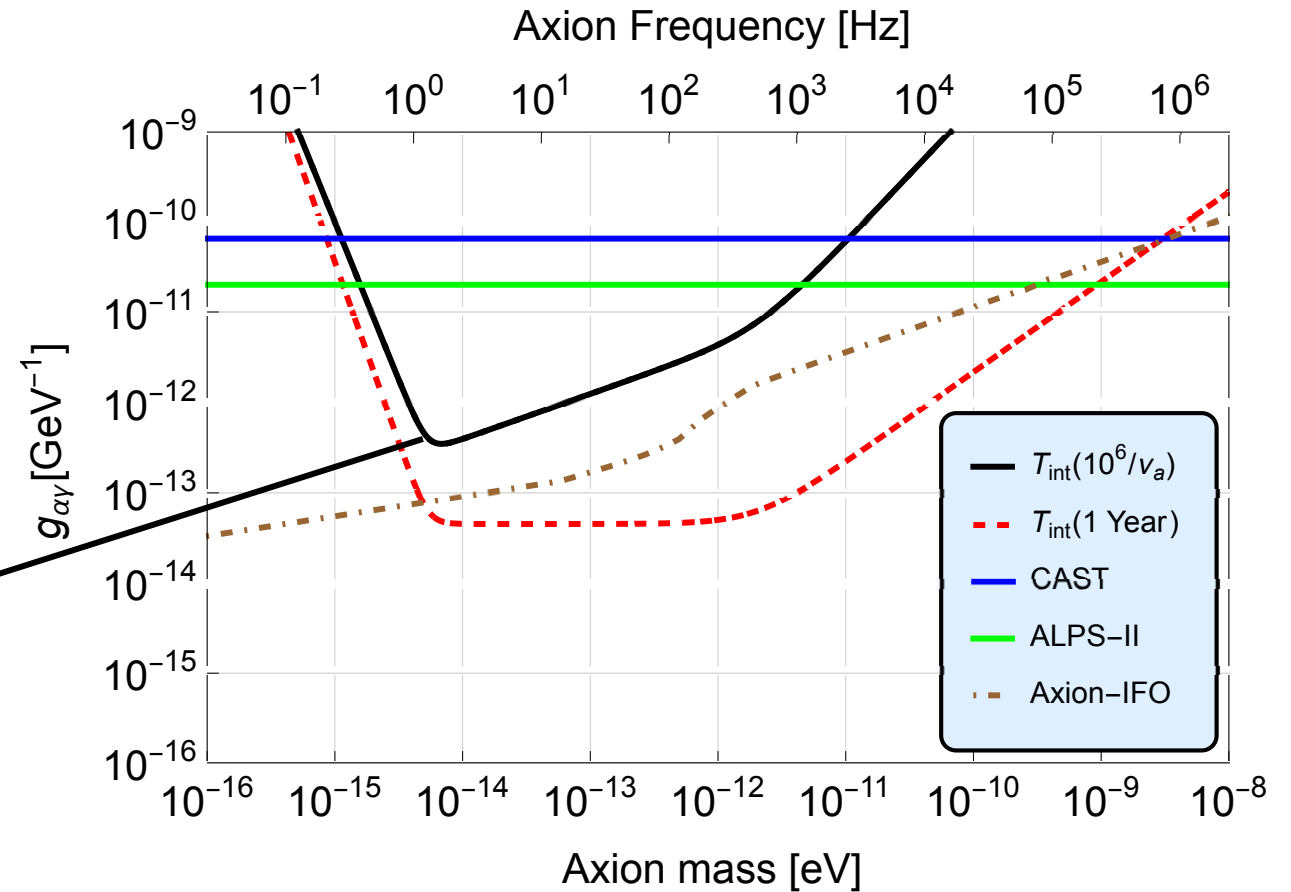


Prospects for Axion



Input power	I_0	1 W
PDE quantum efficiency	q	0.7 A/W
PDE gain	G	$10^6 \Omega$
Extinction ratio	σ^2	2×10^{-7}
Dark noise	i_{dark}	$25 \text{ fA}_{\text{rms}}/\sqrt{\text{Hz}}$
Modulation amplitude	η_0	1.5×10^{-3}
Modulation frequency	ν_{PEM}	50 kHz
RIN	$N_{\nu_{\text{PEM}}}^{(\text{RIN})}$	$3 \times 10^{-7}/\sqrt{\text{Hz}}$
Seismic noise coupling	γ	0.1
Cavity build-up	N	20 000
Solid/QWP wedge	θ	$1 \mu\text{rad}$

Integrated over the coherence time of dark matter field



- 5-meter-long cavity

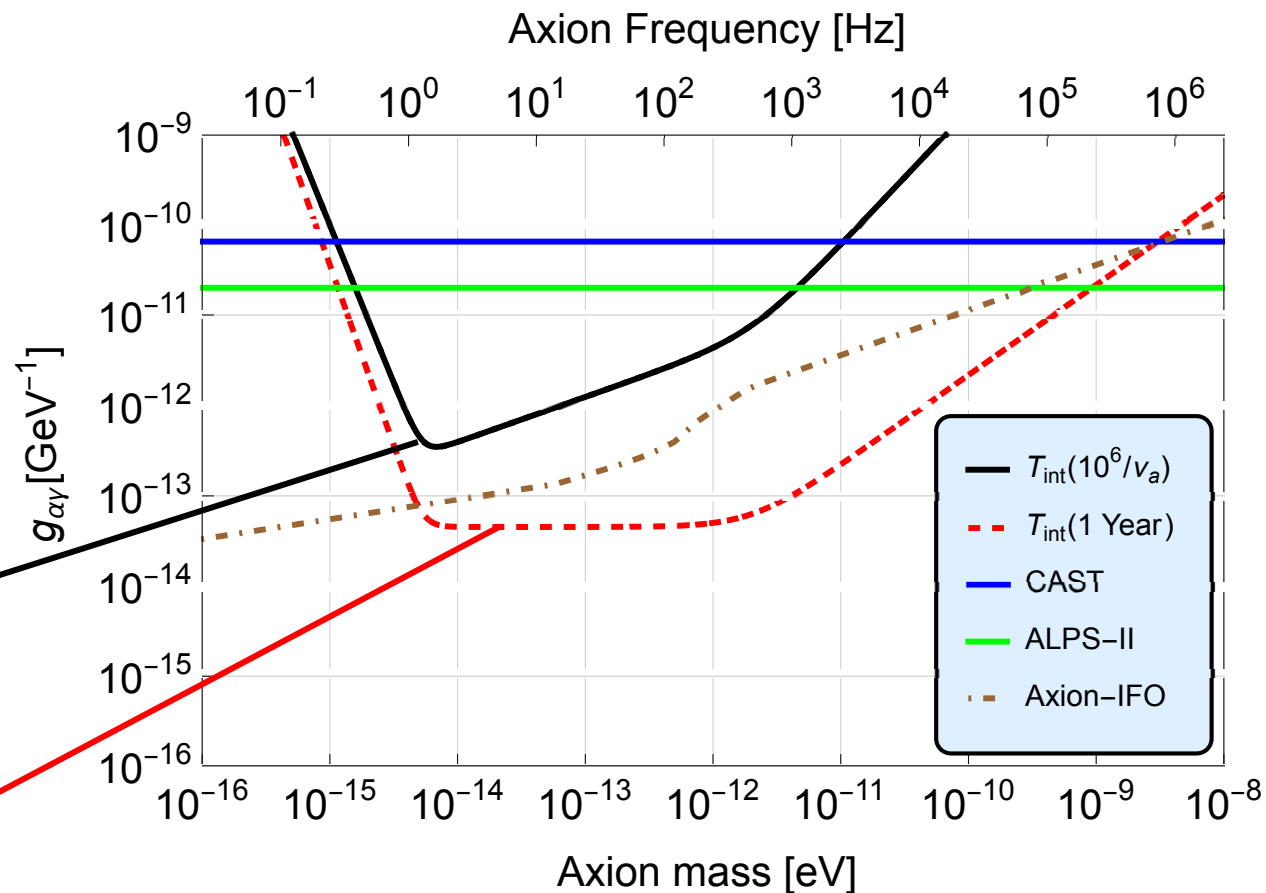
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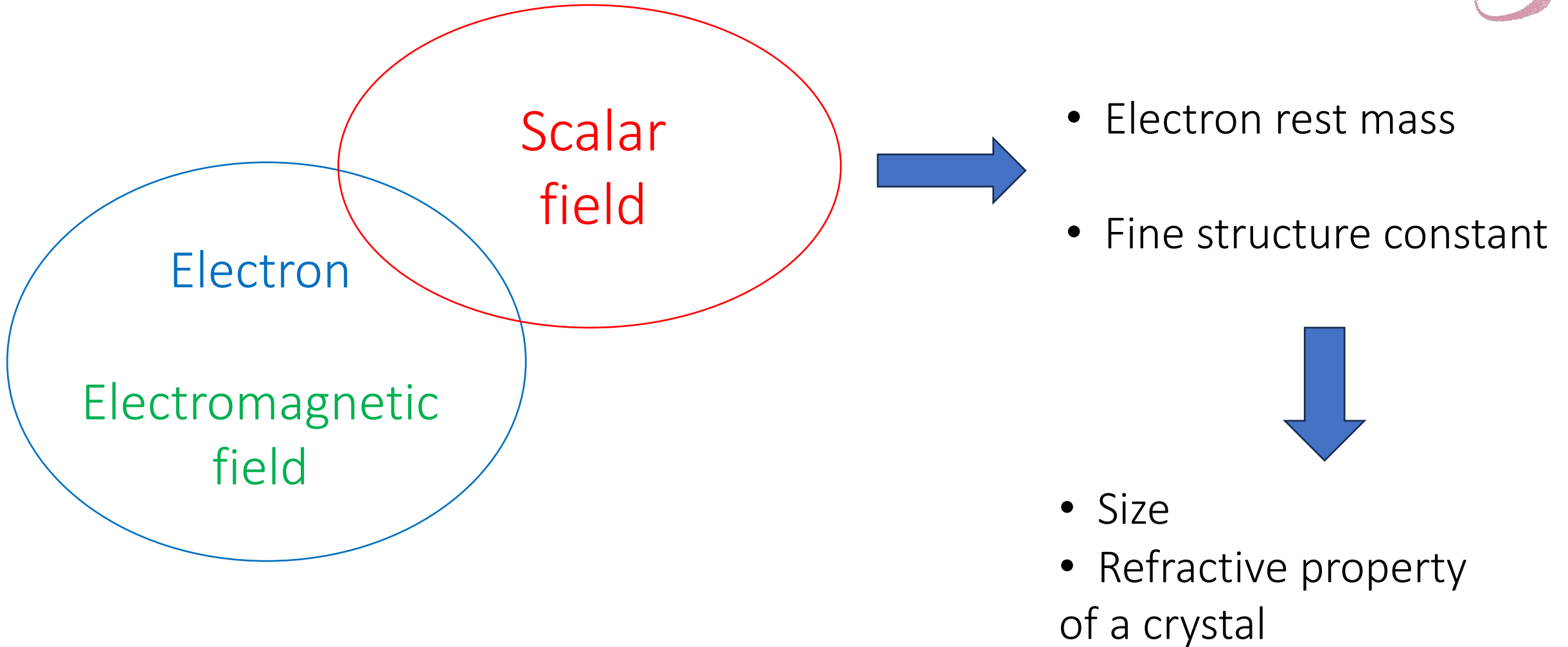
Integrated over one year using twin
polarimetry and cross-correlation

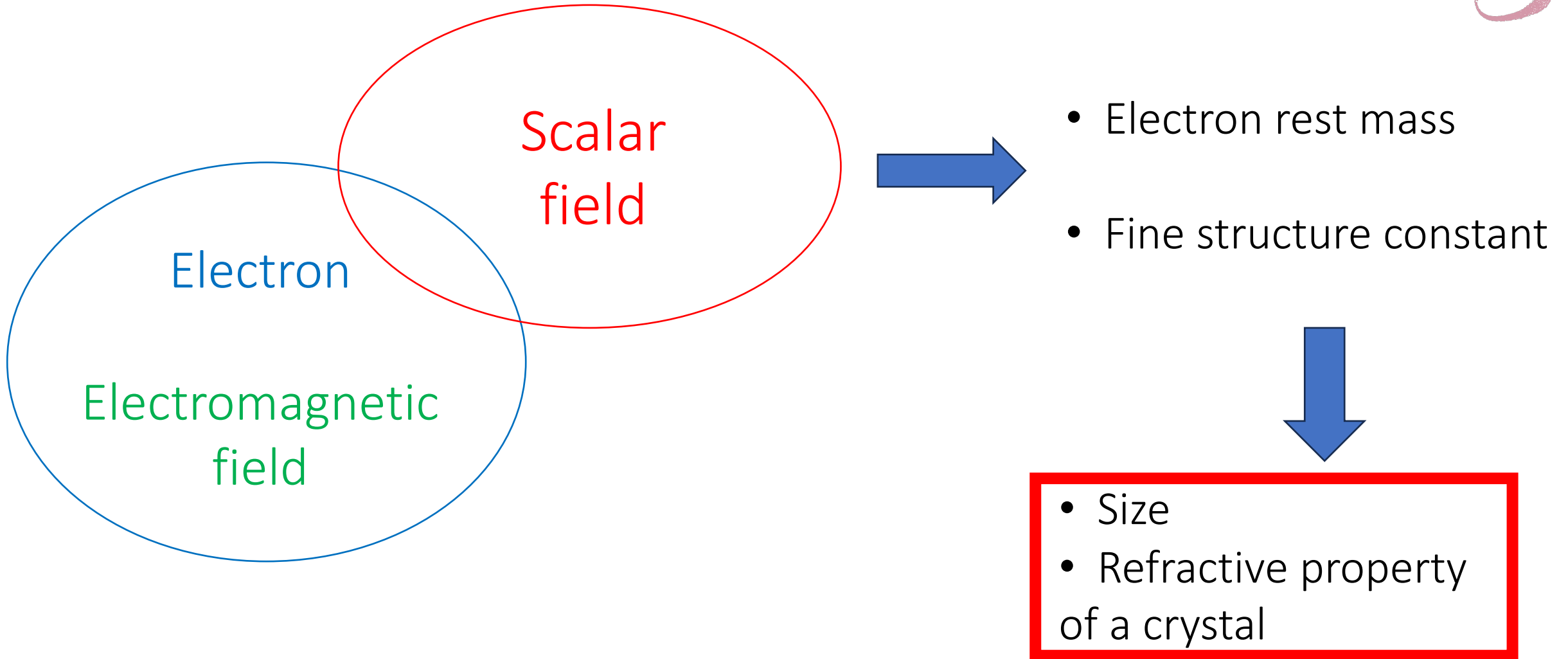


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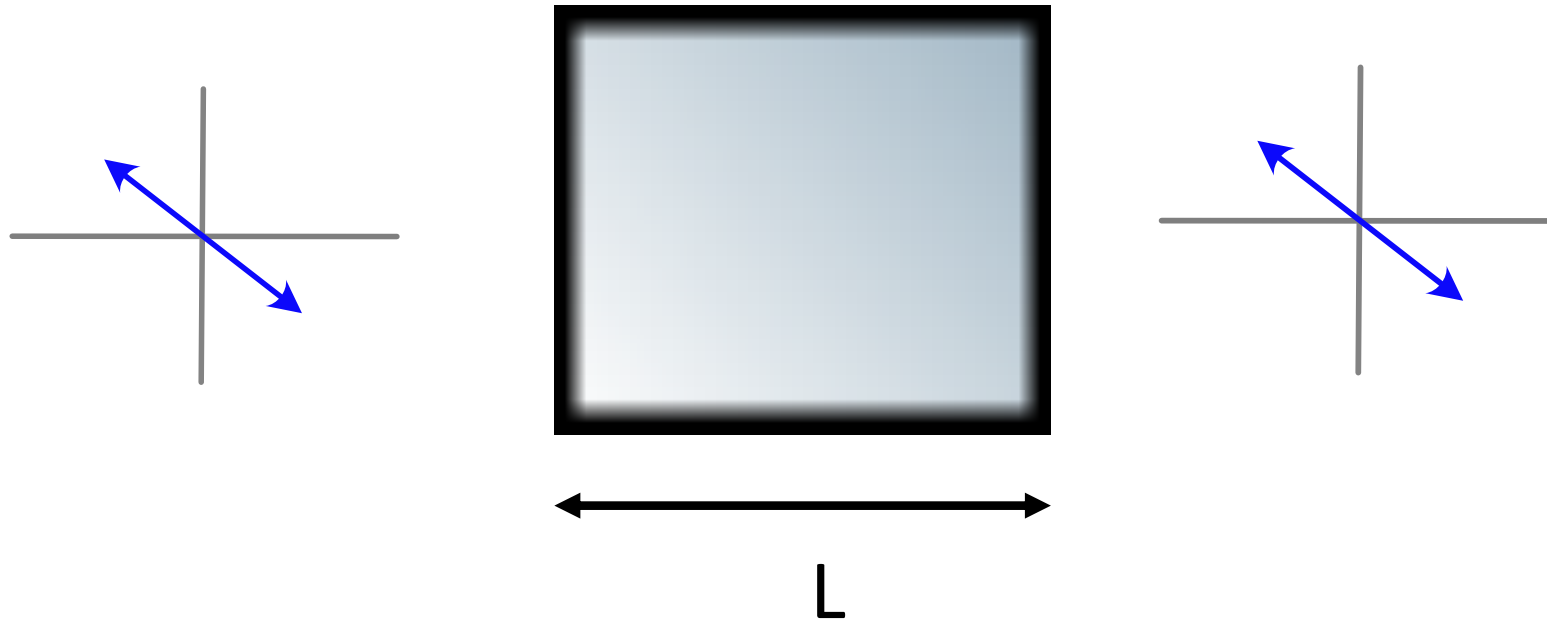
Scalar Field







Full wave plate



Scalar field dark matter effect

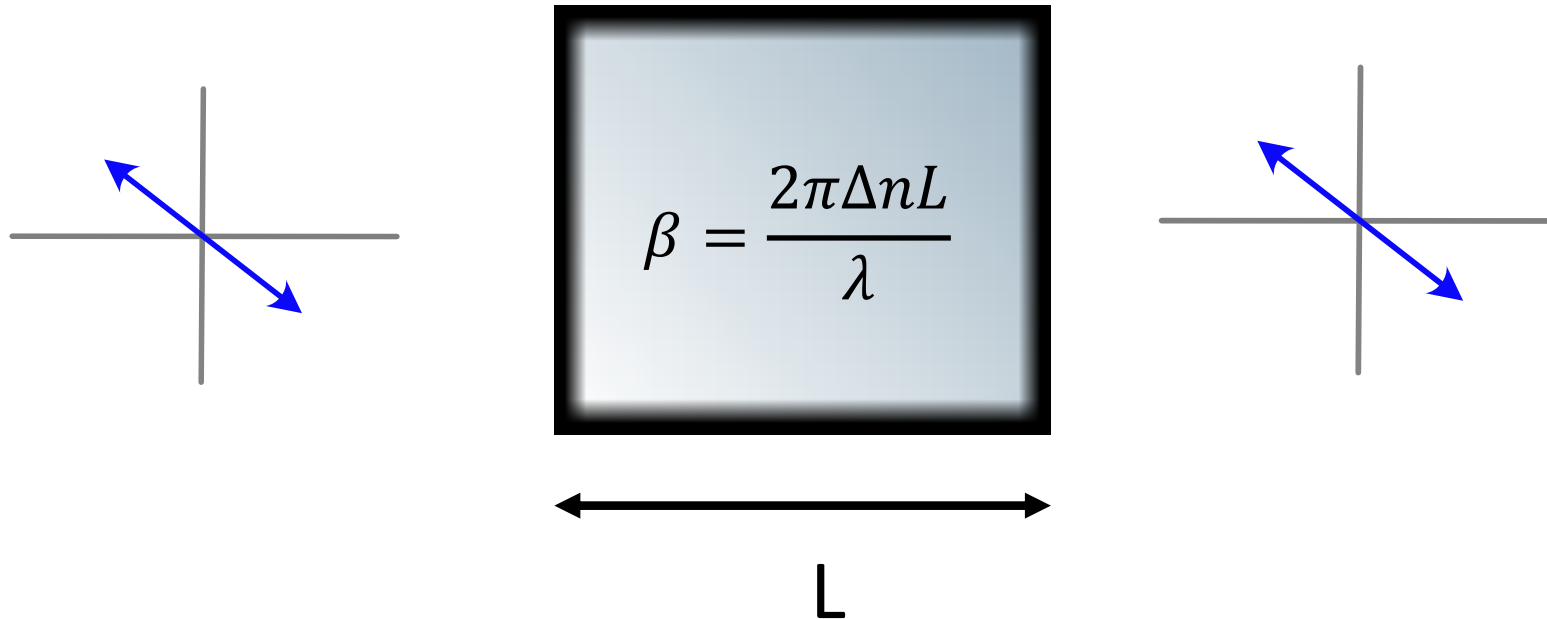


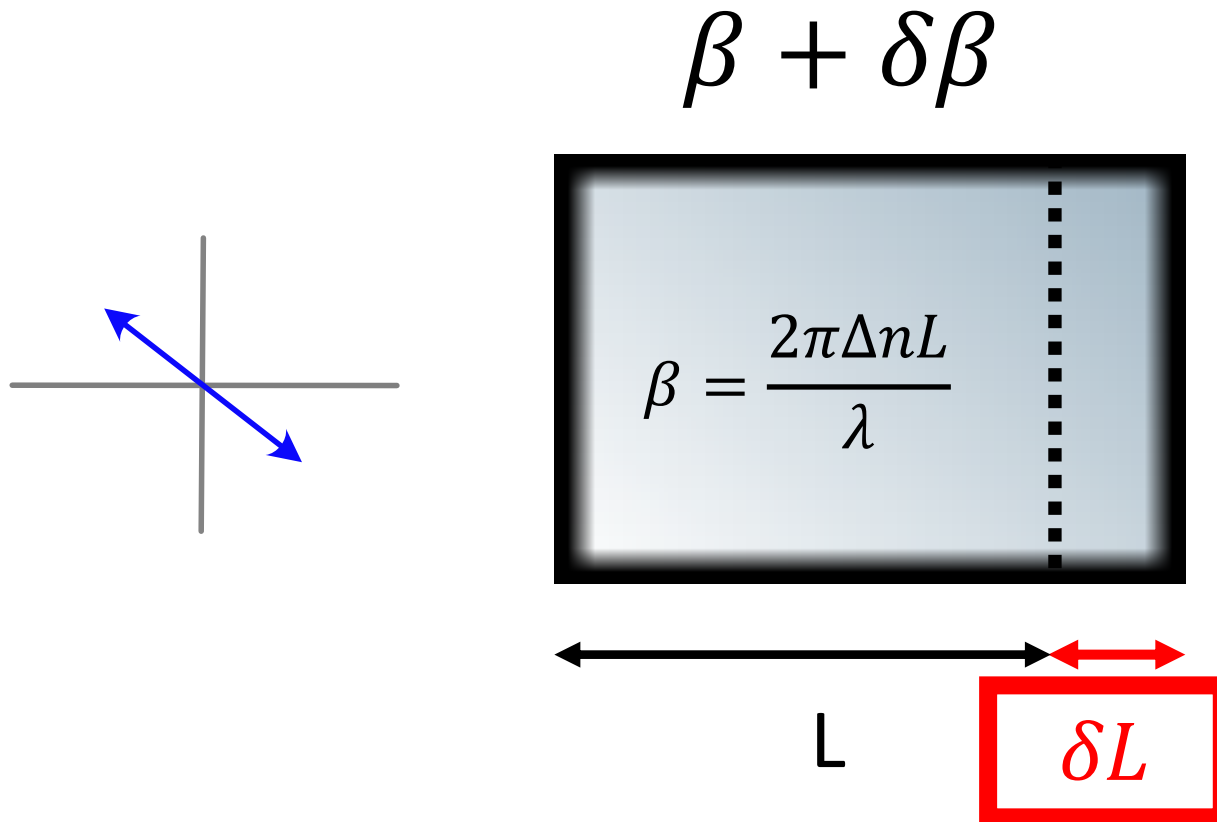
Difference in phase between
orthogonal polarizations

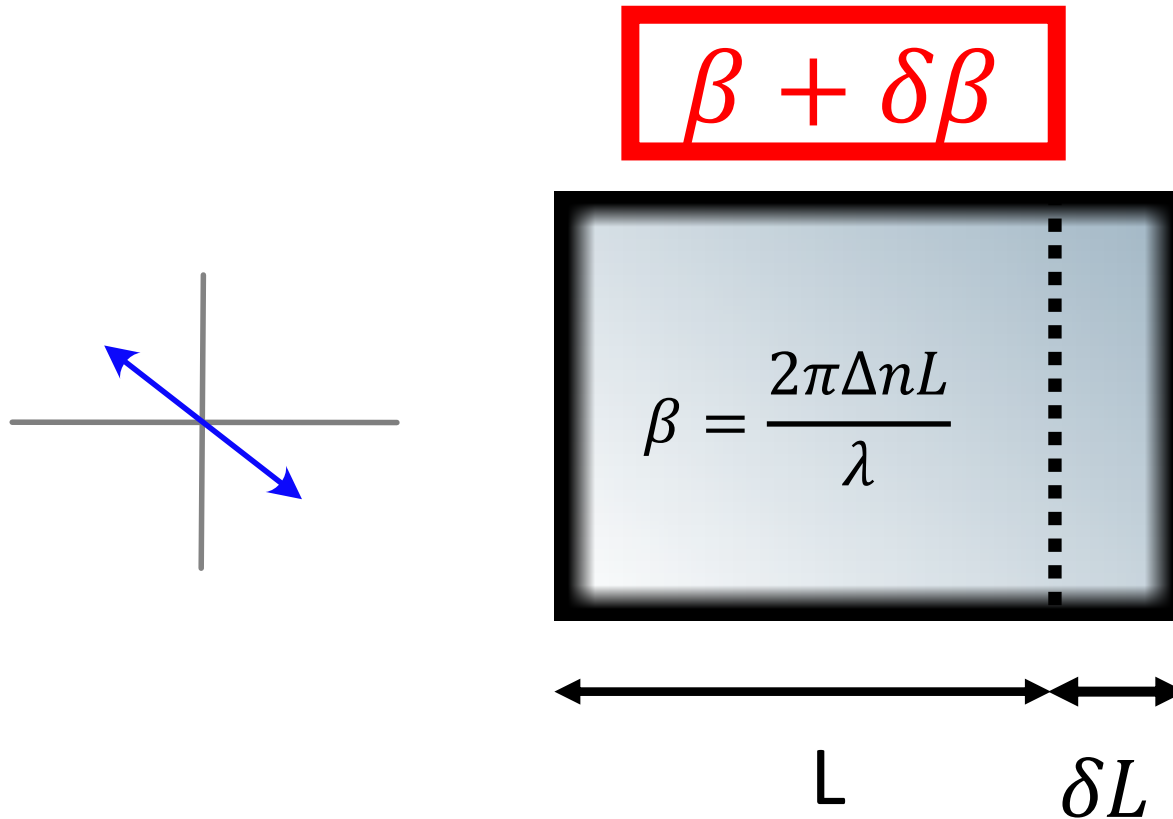
$$\beta = n\pi$$



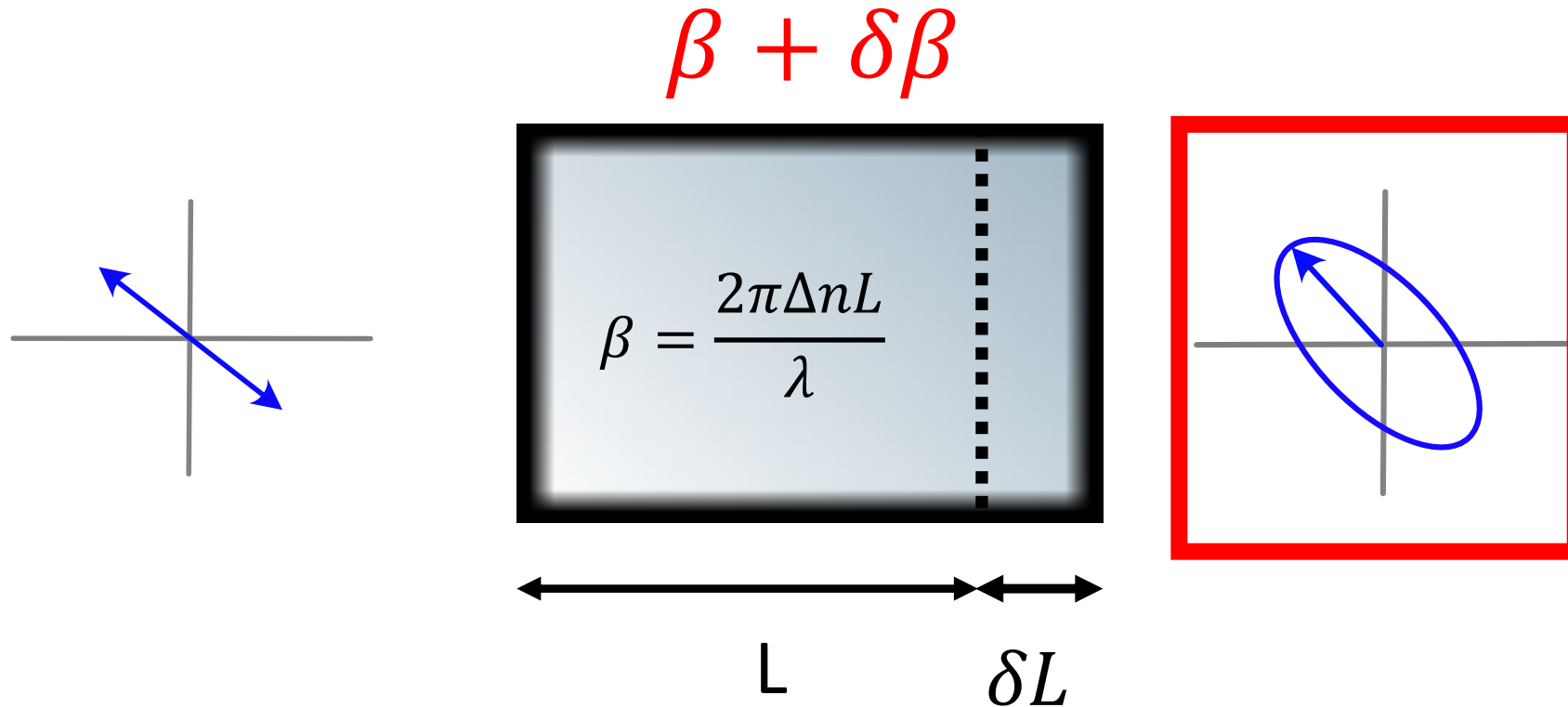
Full wave plate





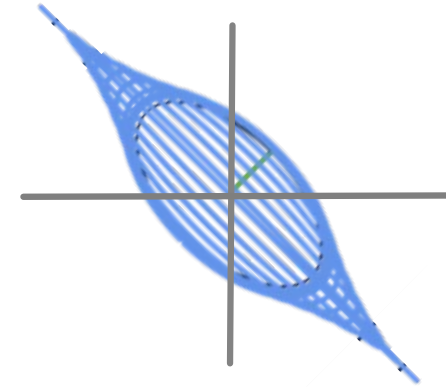
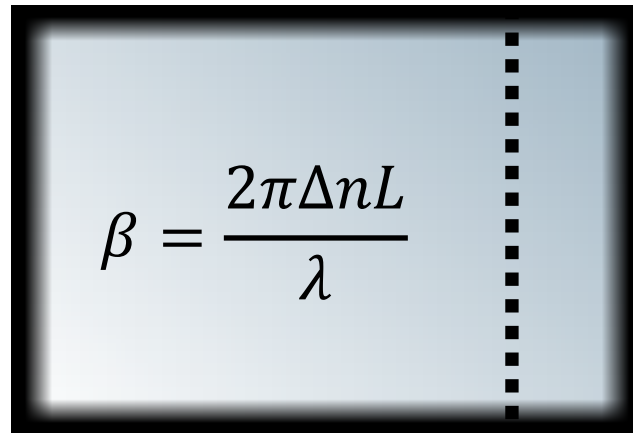
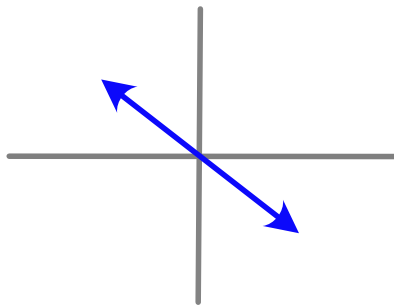


Scalar field dark matter effect

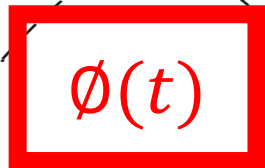




$$\beta + \delta\beta(t)$$



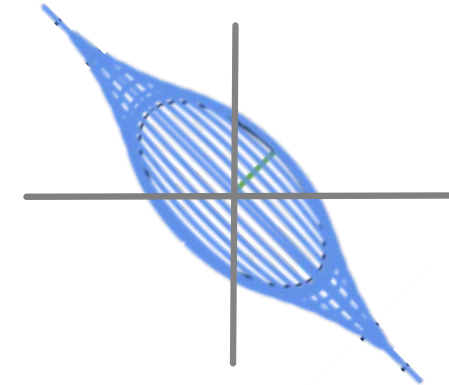
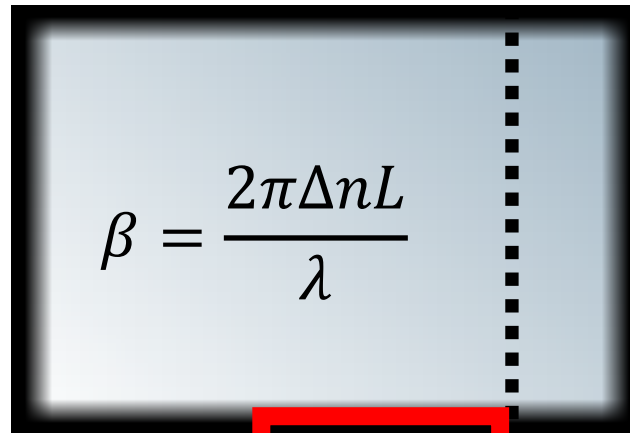
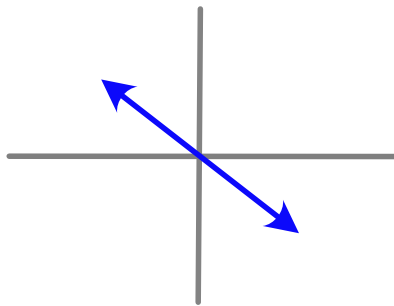
Scalar field



$$\delta L(t)$$



$$\beta + \delta\beta(t)$$



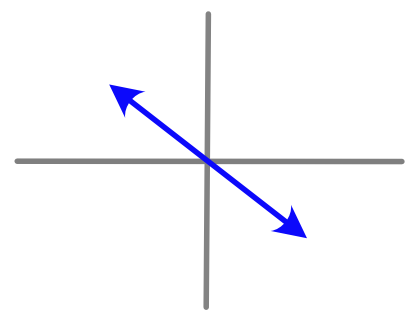
Scalar field

$$\phi(t)$$

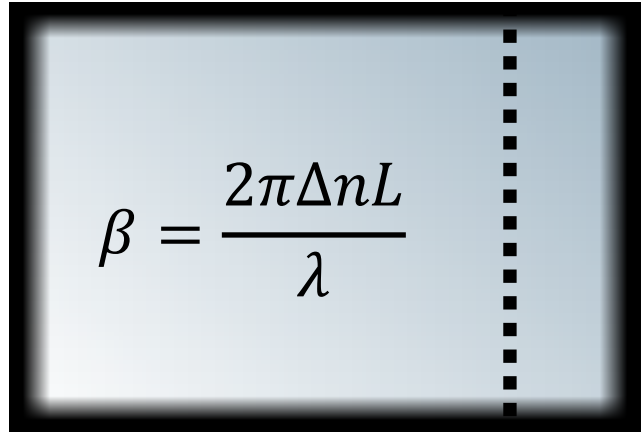
Scalar field dark matter effect



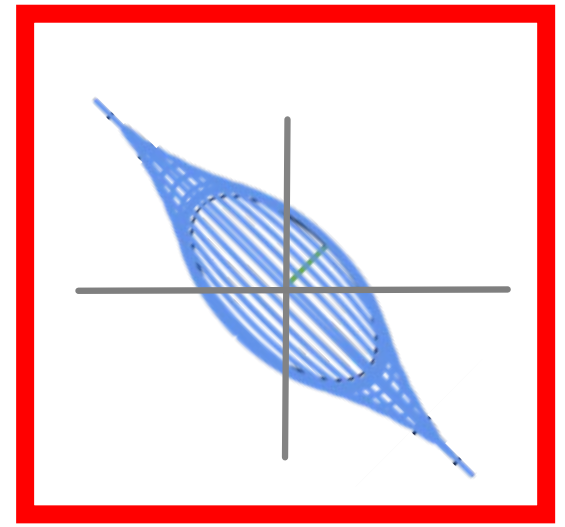
$$\beta + \delta\beta(t)$$



Scalar field



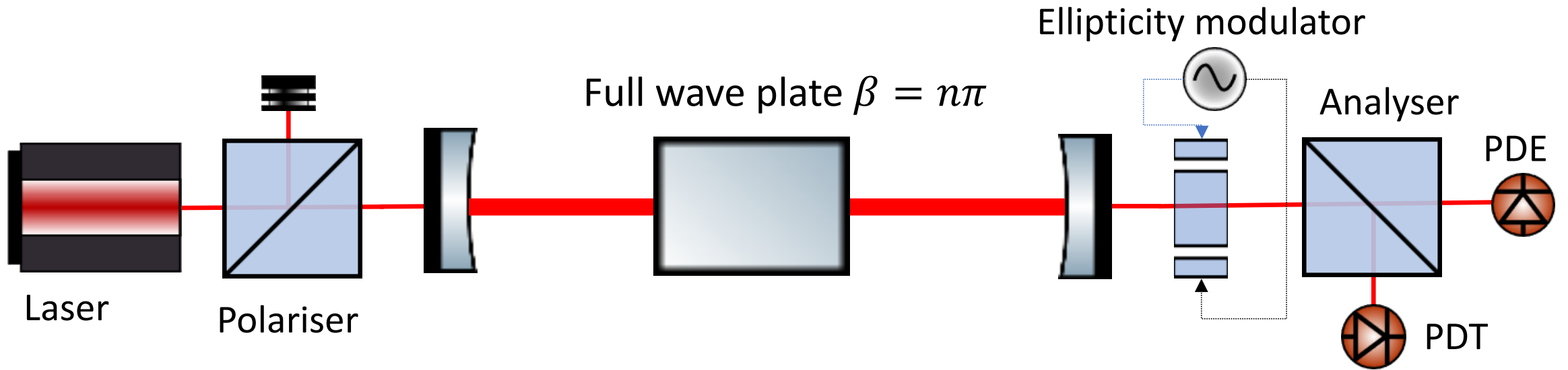
$$\beta = \frac{2\pi\Delta nL}{\lambda}$$



$$\delta L(t)$$

$$\phi(t)$$

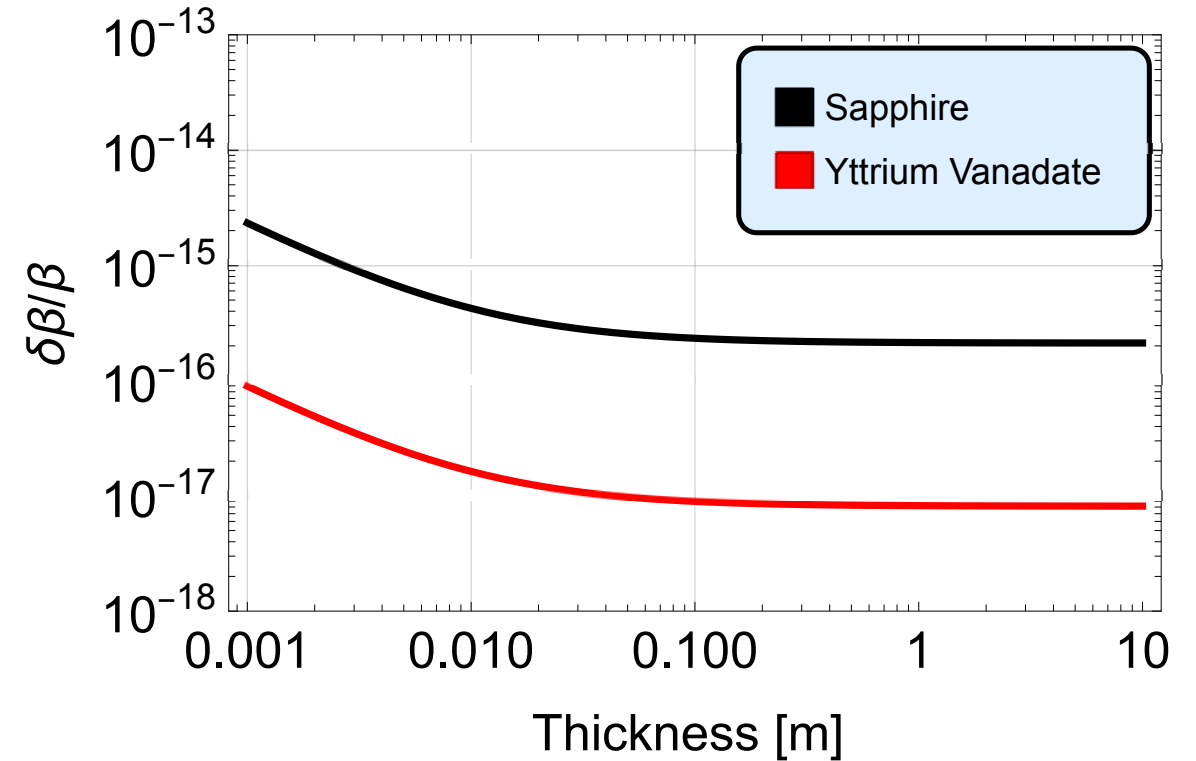
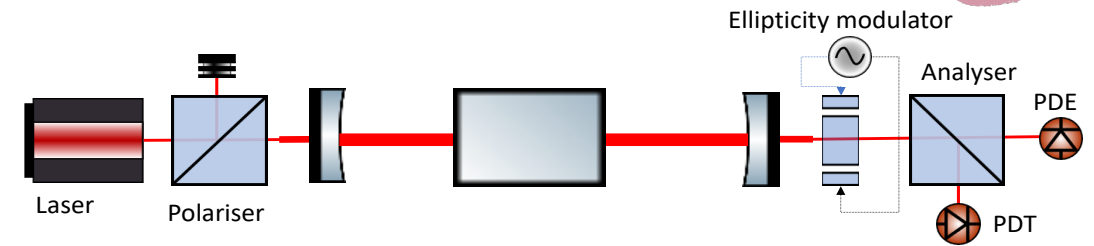
Proposed set up for Scalar field detection



Sensitivity enhancement



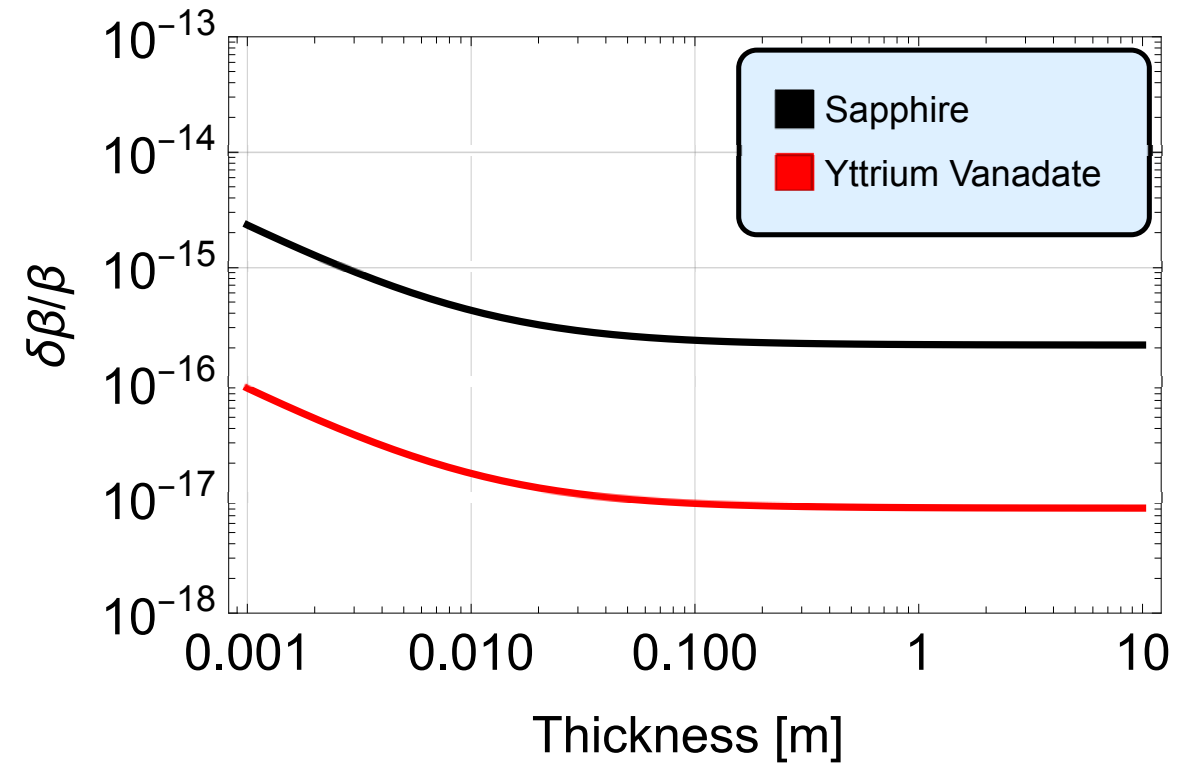
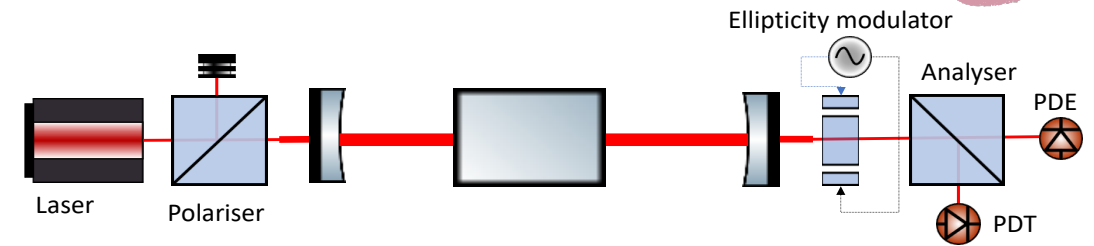
- Scalar field affects materials differently



Sensitivity enhancement



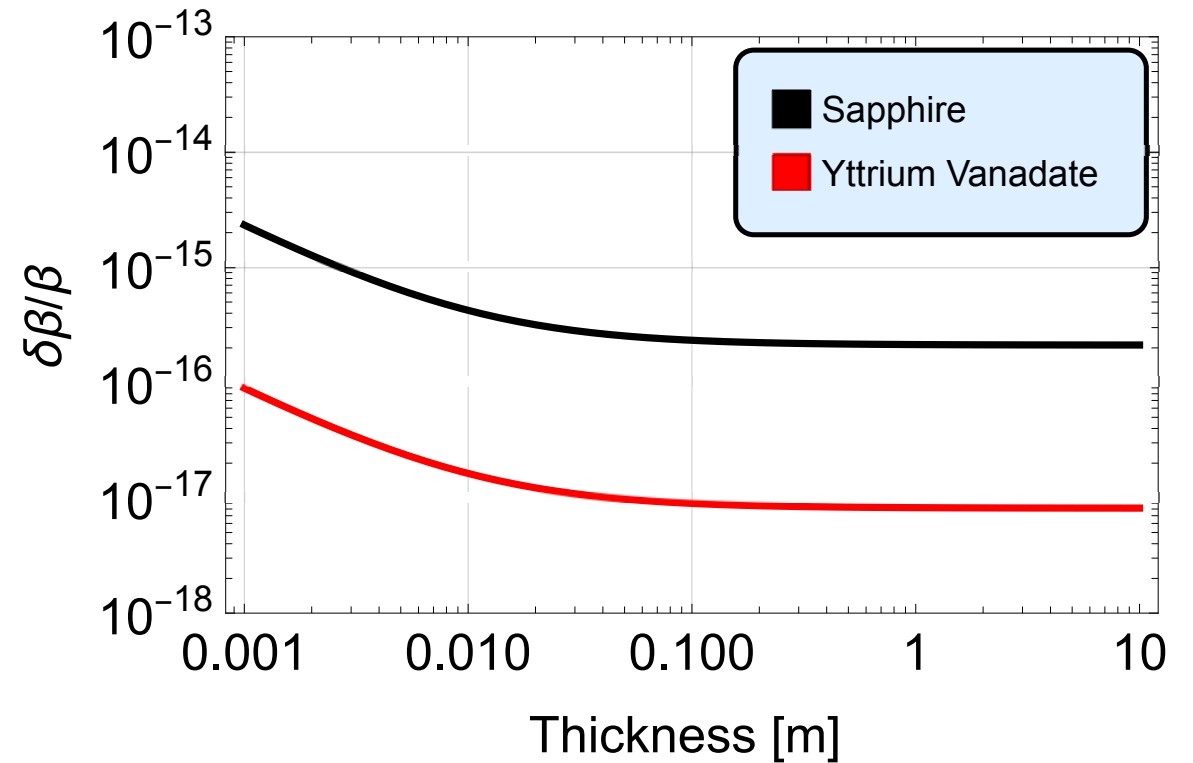
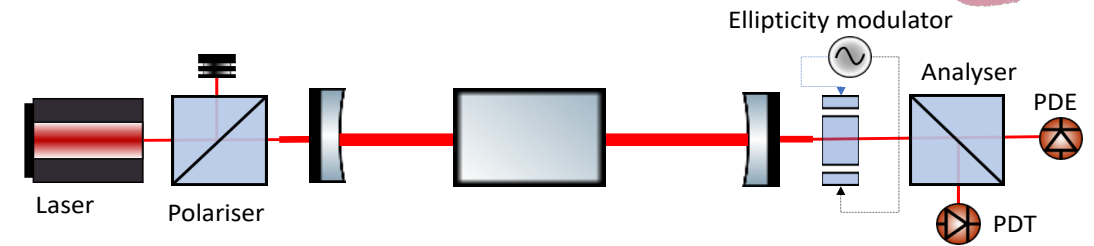
- Scalar field affects materials differently
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Sensitivity enhancement



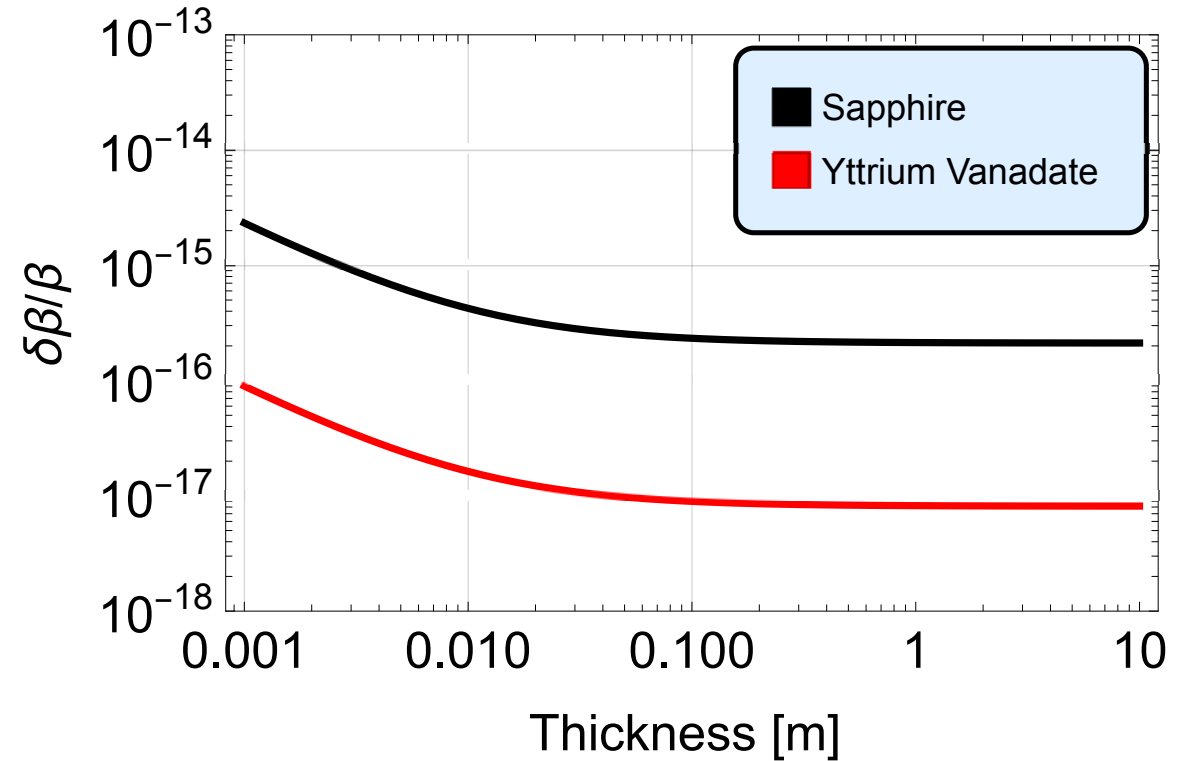
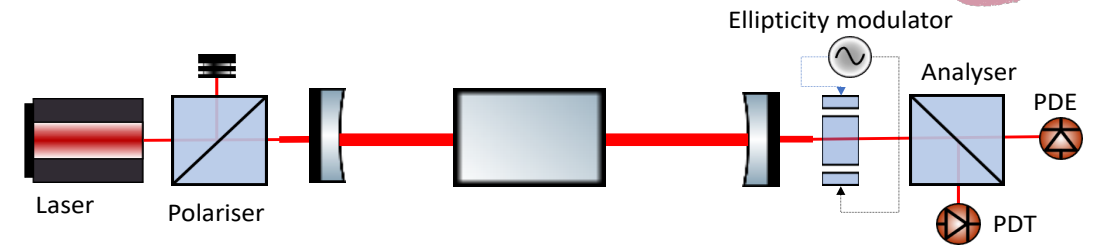
- Scalar field affects materials differently
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- Crystal losses scale with length of crystal



Sensitivity enhancement



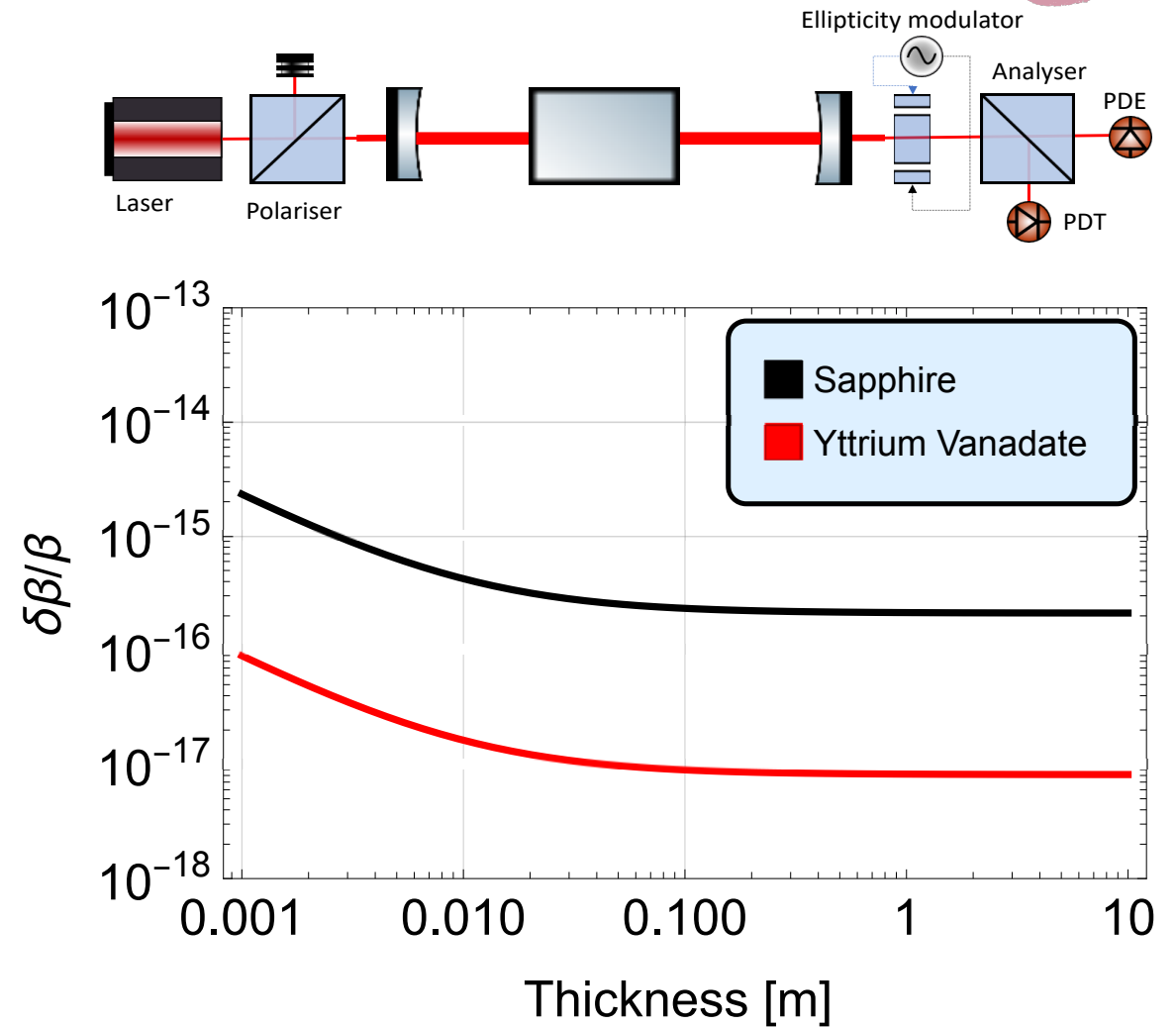
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- Optimum mirror transmissivity for given crystal losses



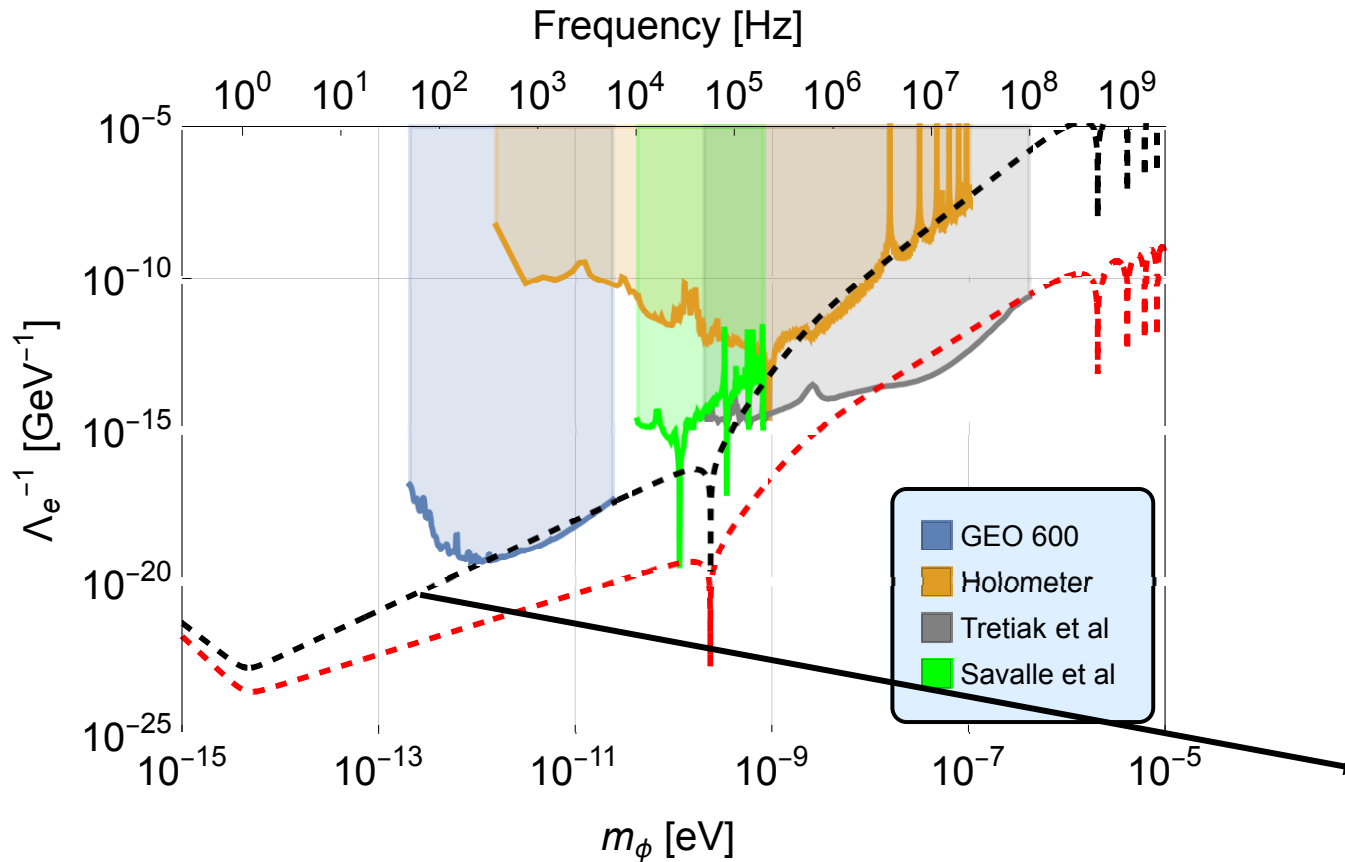
Sensitivity enhancement



- Scalar field affects materials differently
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- Crystal losses scale with length of crystal
- Optimum mirror transmissivity for given crystal losses
- Signal strength for optimum cavity length is independent of crystal length



Prospects for Scalar field

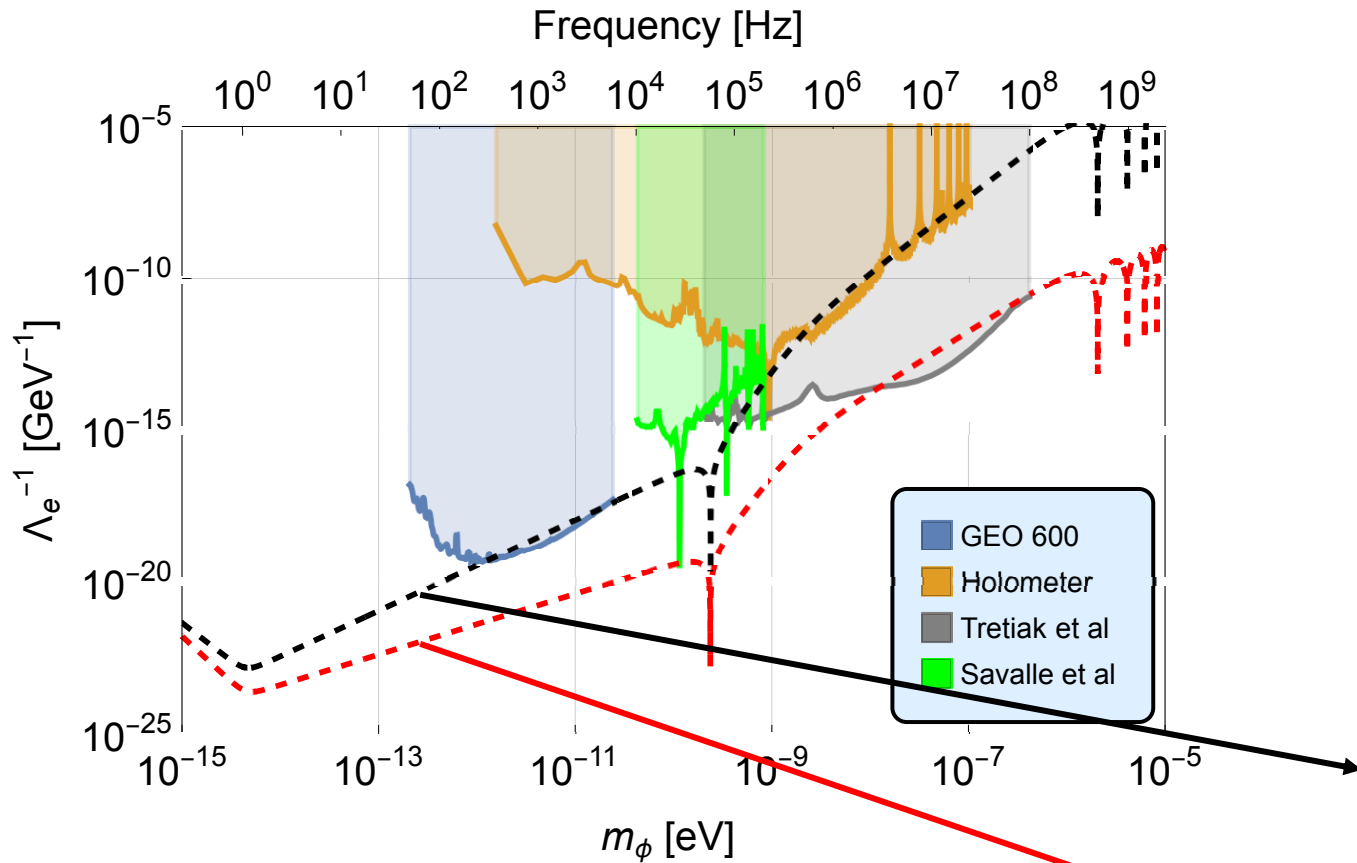


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RIN	$N_{\nu_{\text{PEM}}}^{(\text{RIN})}$	$3 \times 10^{-7}/\sqrt{\text{Hz}}$
Seismic noise coupling	γ	0.1
Cavity build-up	N	20 000
Solid/QWP wedge	θ	$1 \mu\text{rad}$
Yttrium Vanadate	C	12×10^{-3}

Integrated over the coherence time of dark matter field

- 30-centimeter-long cavity
- 5-centimeter-thick Yttrium vanadate crystal

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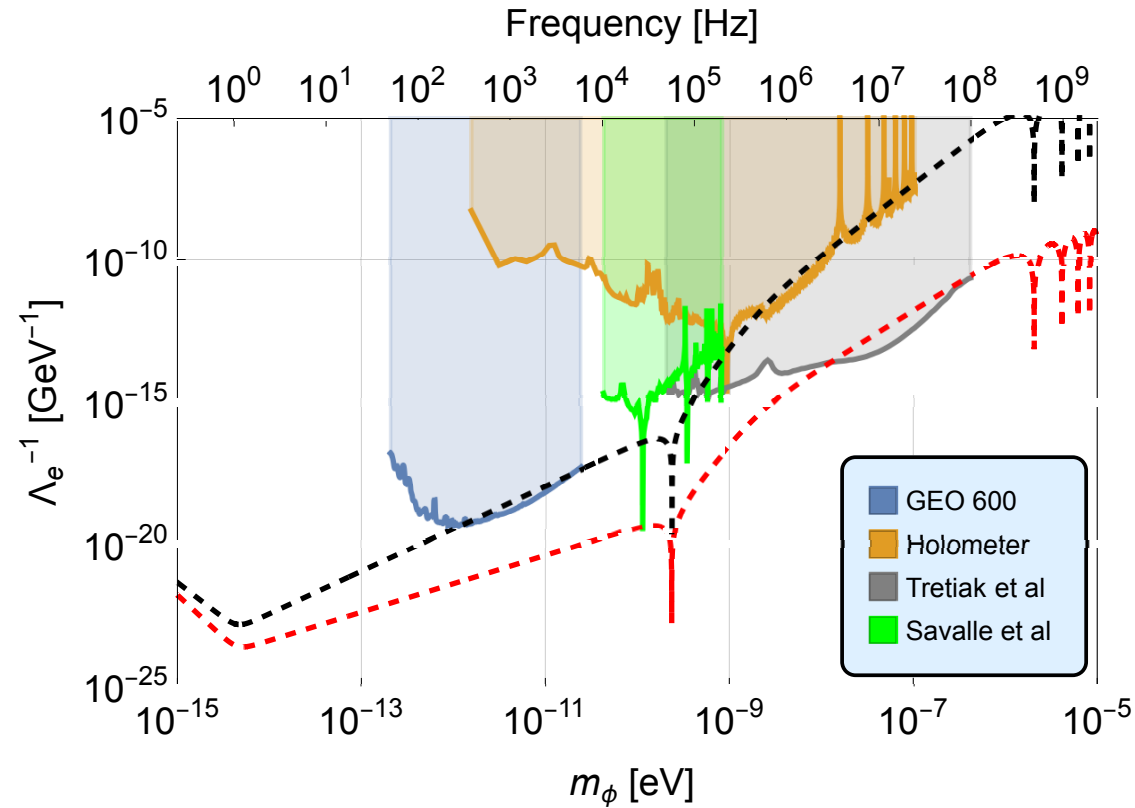
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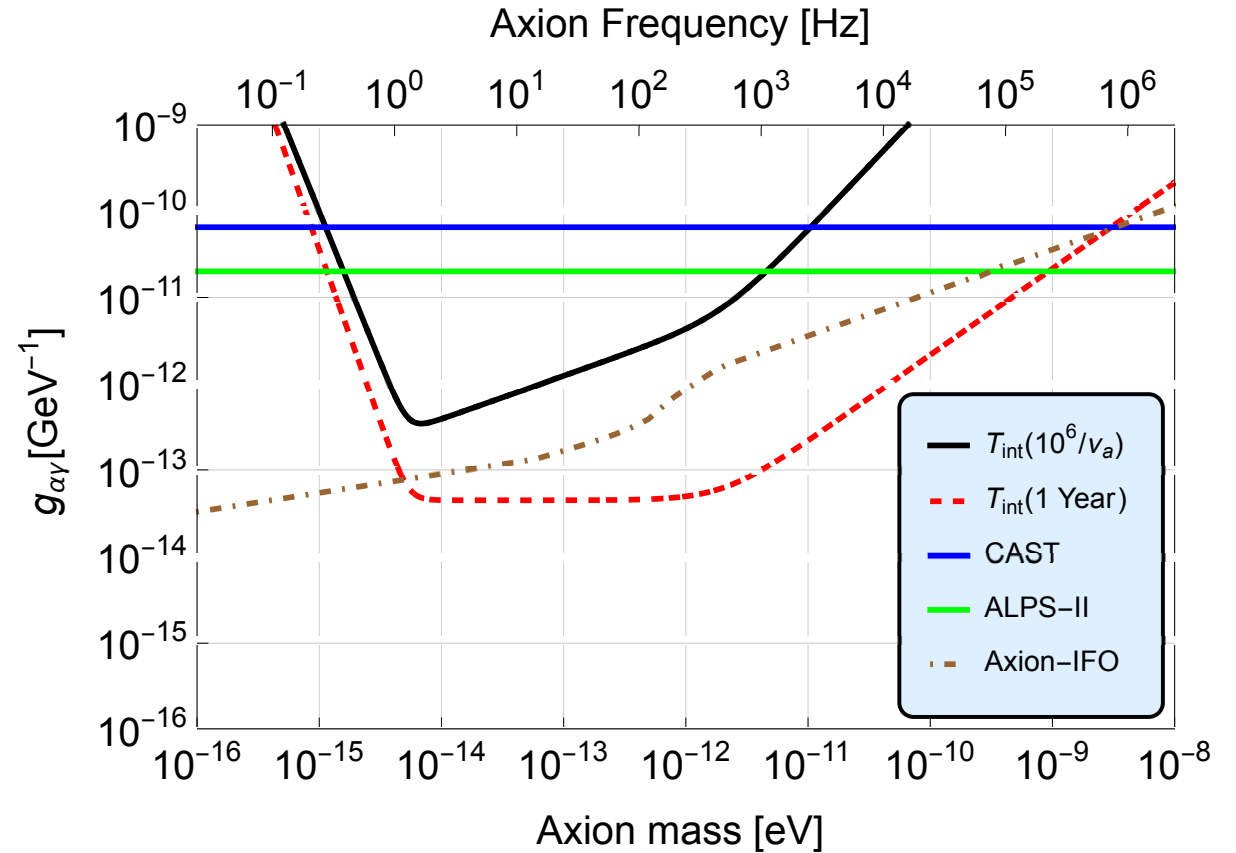
Conclusion



Scalar field



Axion





Thank you for your attention

Qazal.rokn@aei.mpg.de