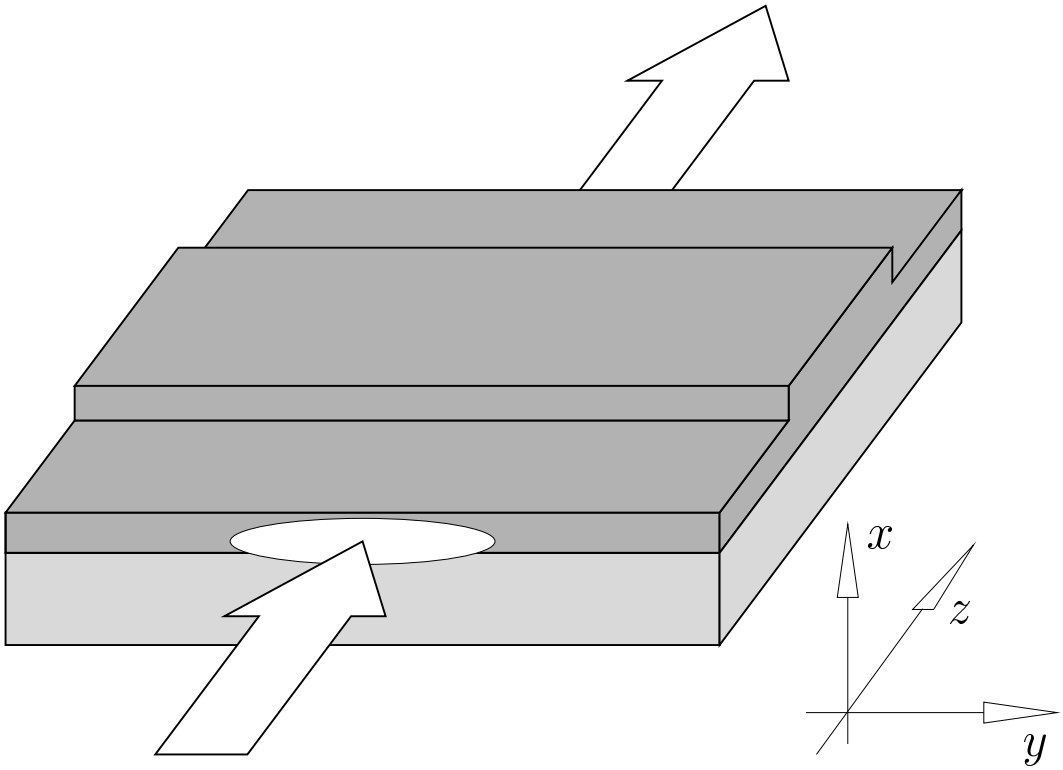
x
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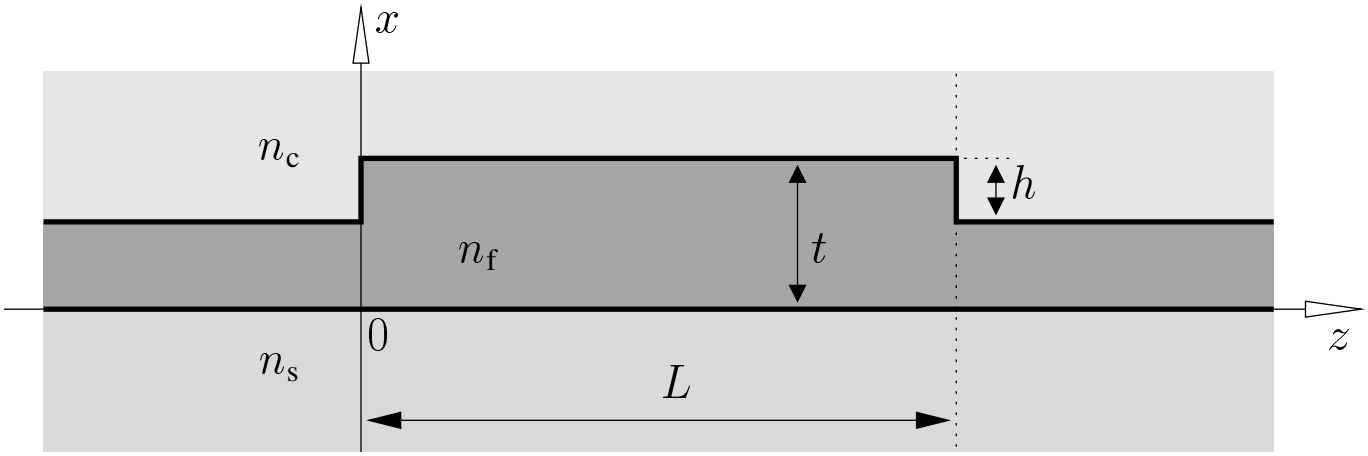
x
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Integrated optical cross strip interferometer

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- Cross strip interferometer
  - Overlap model
  - Geometry optimization
  - Interferometer performance
- Polarizer device
- Magnetooptic isolator
- Summary

Integrated Optics Devices V — Optoelectronics 2001 — Photonics West 2001
San Jose, California, USA *20 – 26 January 2001*

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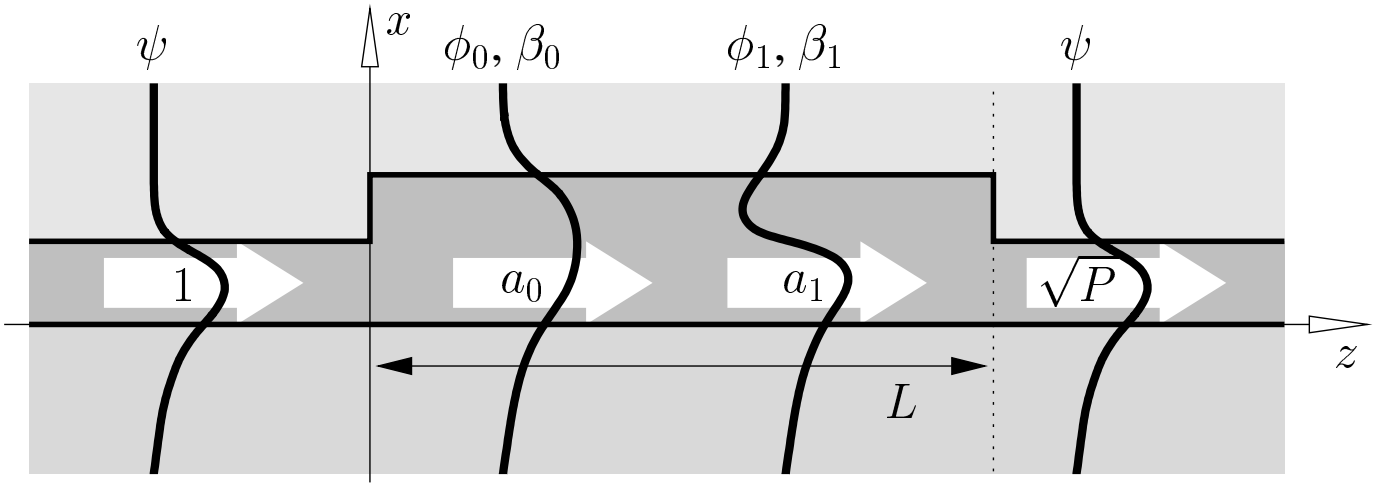


Ingredients:

ψ: input / output mode field,
ϕ_0, ϕ_1: fundamental and first order mode of the strip segment,
β_0, β_1: the corresponding propagation constants,
$(\,.\,,\,.\,)$: a suitable bilinear product.

Relative power transfer:

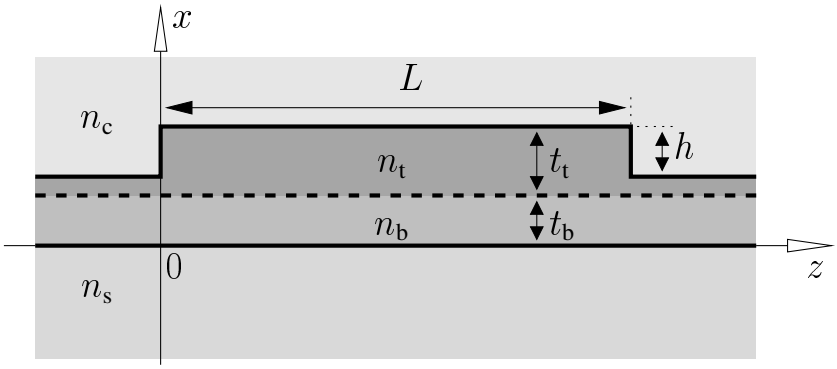
$$P(L) = w_0^2 + w_1^2 + 2w_0 w_1 \cos(\pi L / L_\mathrm{c})\,,$$

with $\quad a_j = (\psi, \phi_j)\,, \quad w_j = a_j^2\,, \quad L_\mathrm{c} = \dfrac{\pi}{\beta_0 - \beta_1}\,.$

L: the length of the thick section.

Modulation range of the transmission:

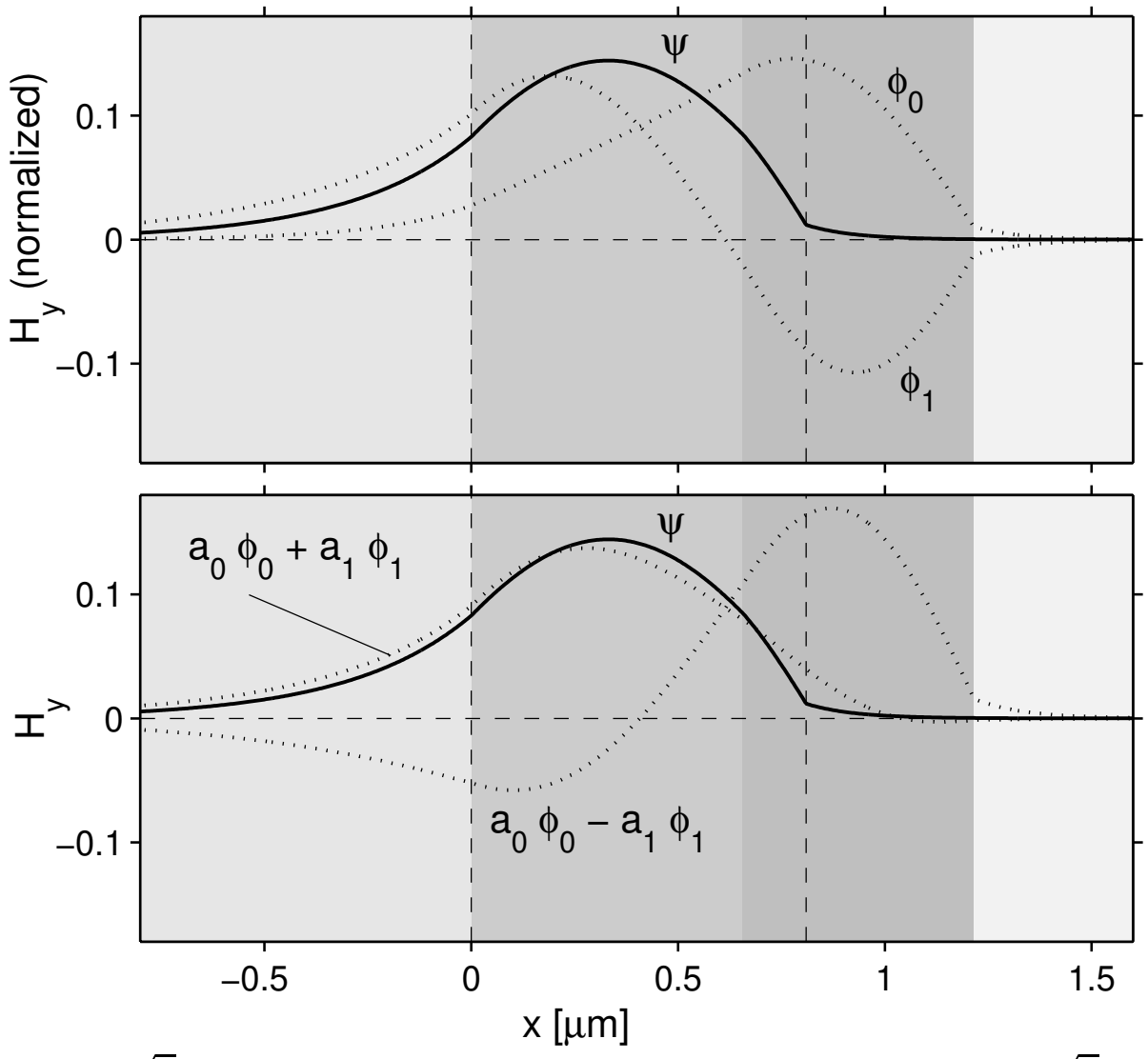
$$(w_0 - w_1)^2 \le P \le (w_0 + w_1)^2\,.$$



$t_b = 0.656\,\mu$m, $t_t = 0.559\,\mu$m,
$h = 0.405\,\mu$m, $\lambda = 1.3\,\mu$m,
$n_s = 1.950$, $n_b = 2.157$,
$n_t = 2.275$, $n_c = 1.0$.

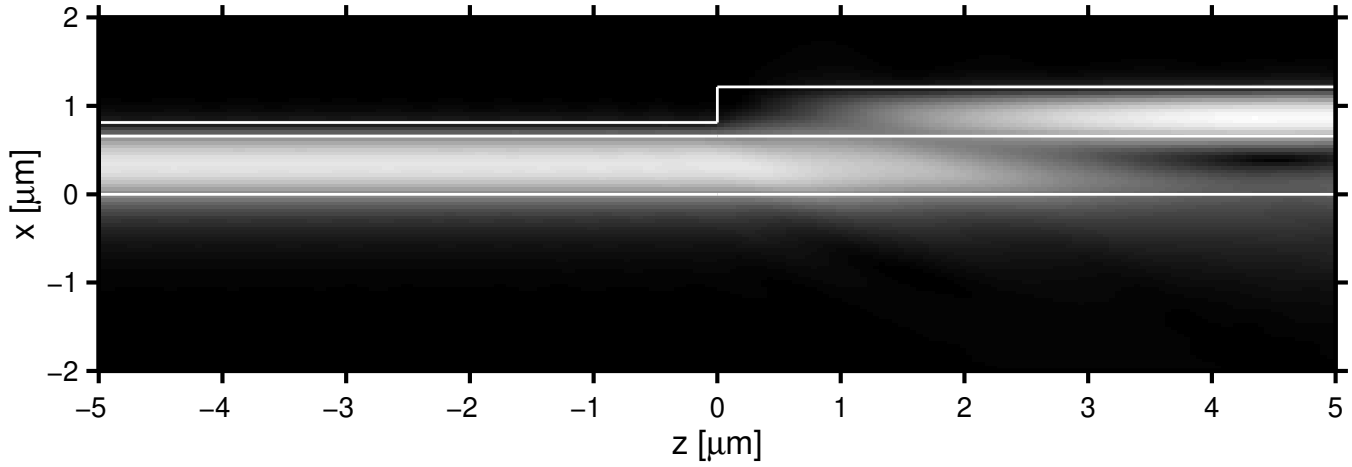
$$(w_0 - w_1)^2 \le P \le (w_0 + w_1)^2, \quad w_0 = (\psi, \phi_0)^2, \quad w_1 = (\psi, \phi_1)^2.$$

Adjust $t_b + t_t$ and h for $w_0 = w_1$ and maximum $(w_0 + w_1)^2$:

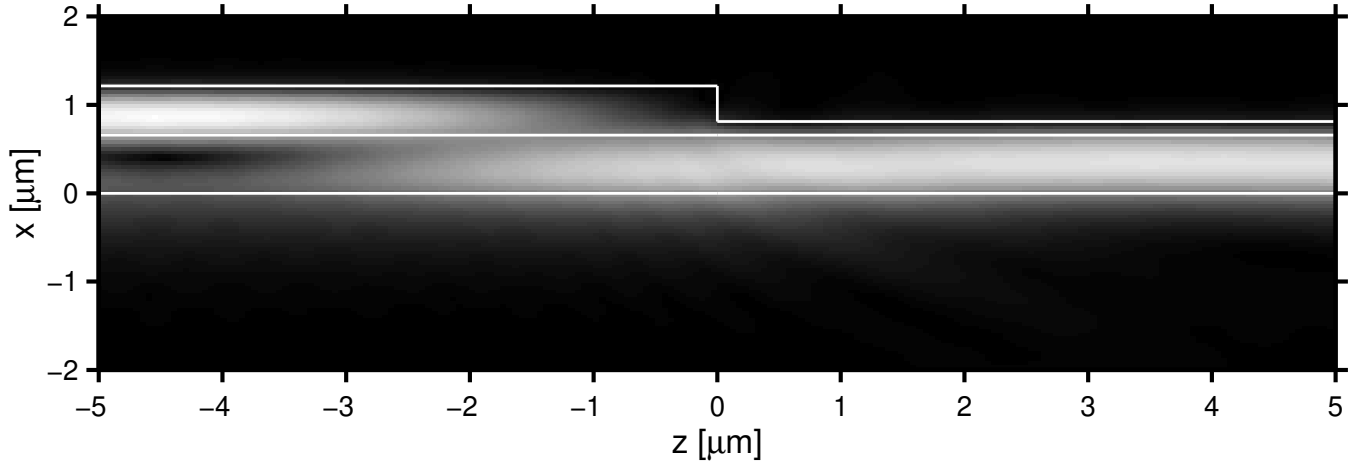


$(\phi_0 + \phi_1)/\sqrt{2} \approx \psi$, $(\phi_0 - \phi_1)/\sqrt{2} \perp \psi$.

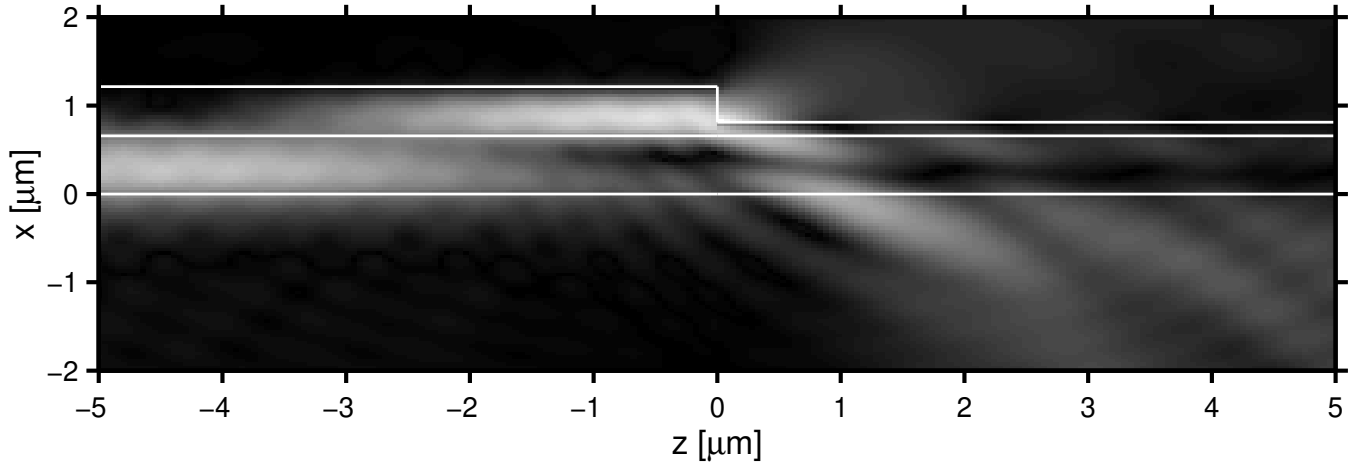
Low losses / reflections at the input junction:

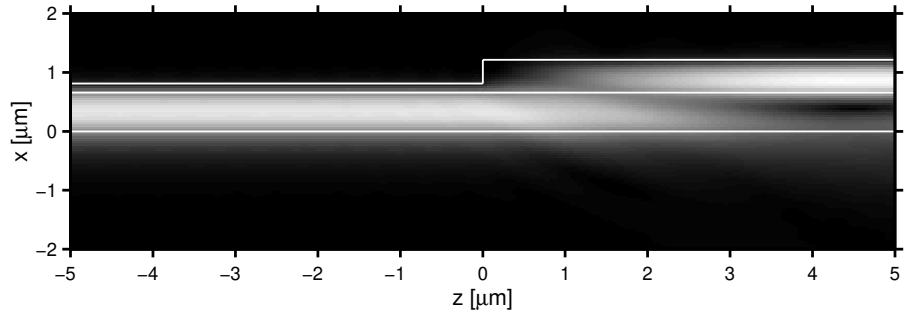


Complete constructive . . .



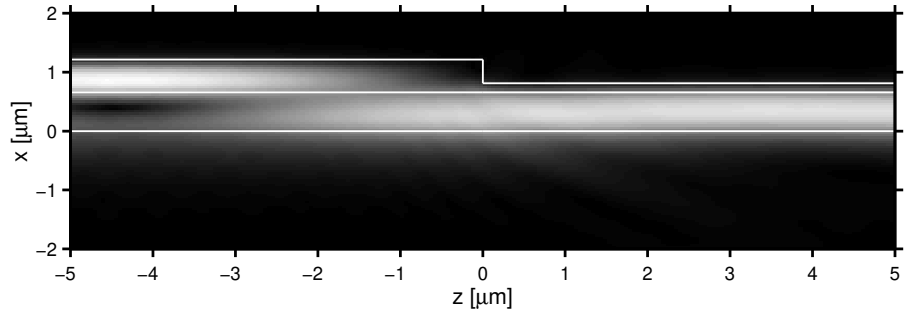
. . . or destructive interference at the output junction:





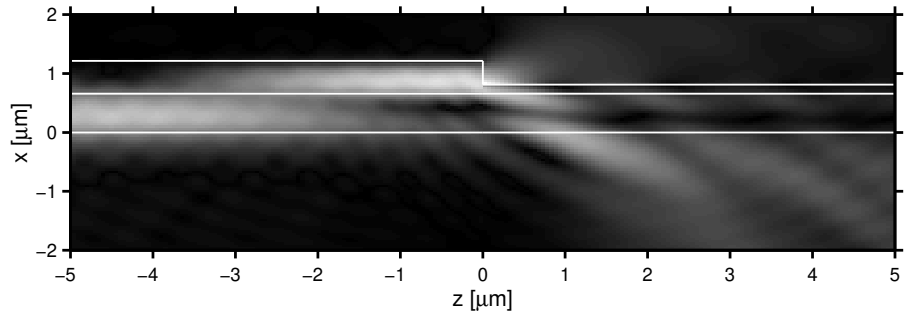
Input: ψ

	$\psi, \rightarrow$	$\psi, \leftarrow$	$\phi_0, \rightarrow$	$\phi_0, \leftarrow$	$\phi_1, \rightarrow$	$\phi_1, \leftarrow$
ME	1	$1.1 \cdot 10^{-6}$	0.49	0	0.50	0
FDTD	1	$3.0 \cdot 10^{-5}$	0.48	0	0.51	0



Input: $(\phi_0 + \phi_1)/\sqrt{2}$

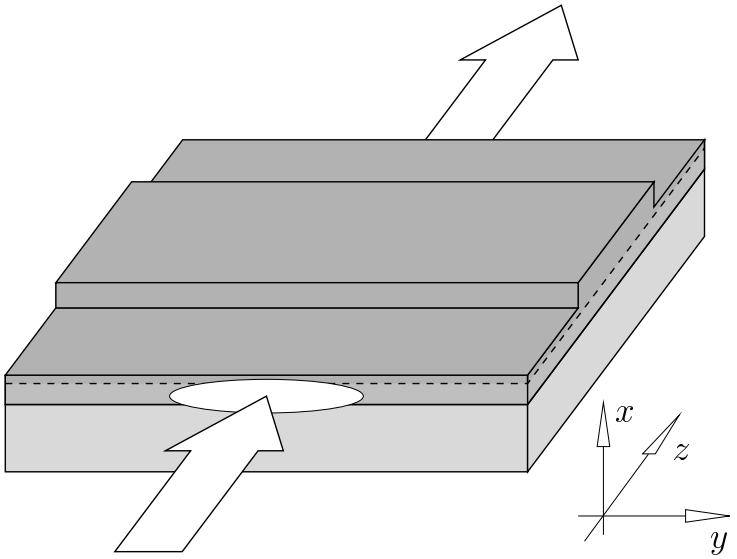
	$\phi_0, \rightarrow$	$\phi_0, \leftarrow$	$\phi_1, \rightarrow$	$\phi_1, \leftarrow$	$\psi, \rightarrow$	$\psi, \leftarrow$
ME	$1/2$	$2.1 \cdot 10^{-4}$	$1/2$	$1.1 \cdot 10^{-4}$	0.99	0
FDTD	$1/2$	$5.0 \cdot 10^{-4}$	$1/2$	$3.0 \cdot 10^{-4}$	0.99	0

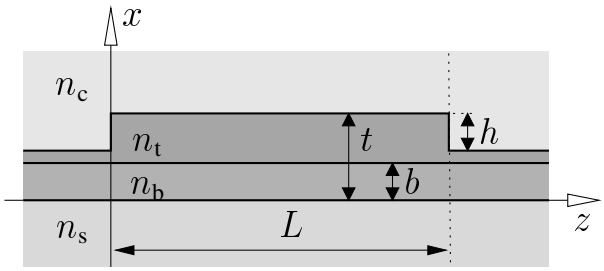


Input: $(\phi_0 - \phi_1)/\sqrt{2}$

	$\phi_0, \rightarrow$	$\phi_0, \leftarrow$	$\phi_1, \rightarrow$	$\phi_1, \leftarrow$	$\psi, \rightarrow$	$\psi, \leftarrow$
ME	$1/2$	$2.0 \cdot 10^{-2}$	$1/2$	$1.3 \cdot 10^{-2}$	$6.5 \cdot 10^{-5}$	0
FDTD	$1/2$	$3.6 \cdot 10^{-2}$	$1/2$	$2.8 \cdot 10^{-2}$	$9.0 \cdot 10^{-4}$	0

$L_c^{TE} \neq L_c^{TM}$: Adjust $L = 2m\, L_c^{TE} = (2m+1) L_c^{TM}$ with natural m.

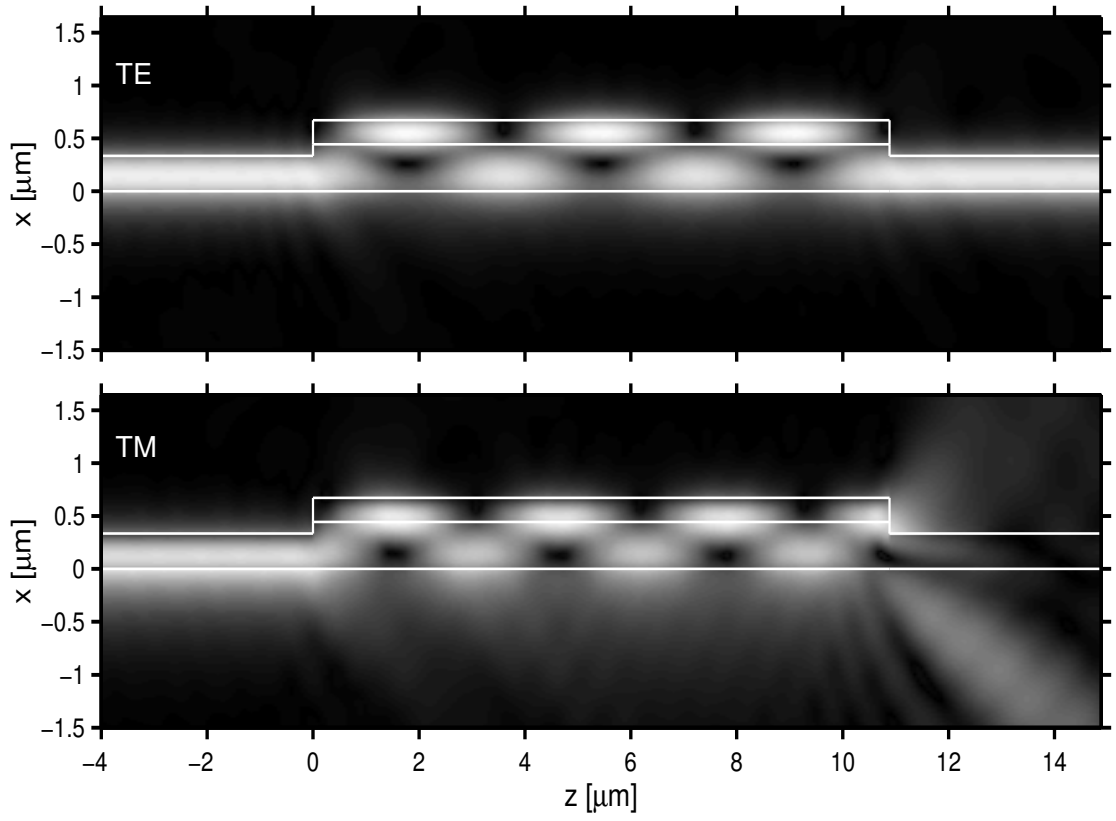




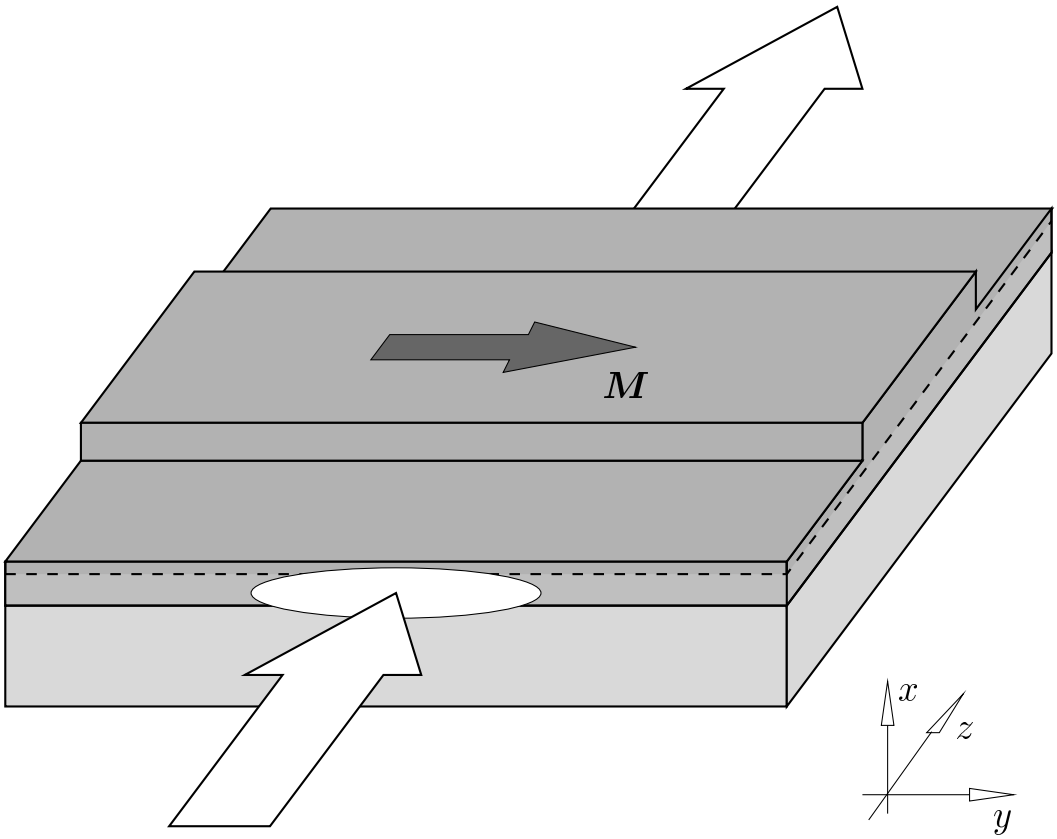
ER $= 10 \log_{10} P^{TE}/P^{TM}$, LO $= -10 \log_{10} P^{TE}$, $q_0 - \Delta q \leq q \leq q_0 + \Delta q$: ER ≥ 20 dB, LO ≤ 1 dB.

	t	b	h	L	λ	n_s	n_b	n_t	n_c
q_0	$0.673\,\mu$m	$0.444\,\mu$m	$0.339\,\mu$m	$10.882\,\mu$m	$1.3\,\mu$m	1.465	2.01	2.3	1.0
Δq	26 nm	9 nm	18 nm	100 nm	20 nm	0.007	0.009	0.024	0.08

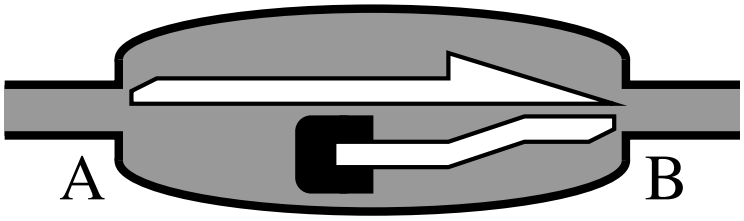
$P^{TE} = 97\%$, $P^{TM} = 0.09\%$, ER $= 30$ dB, LO $= 0.1$ dB, $L = 6L_c^{TE} = 7L_c^{TM}$.

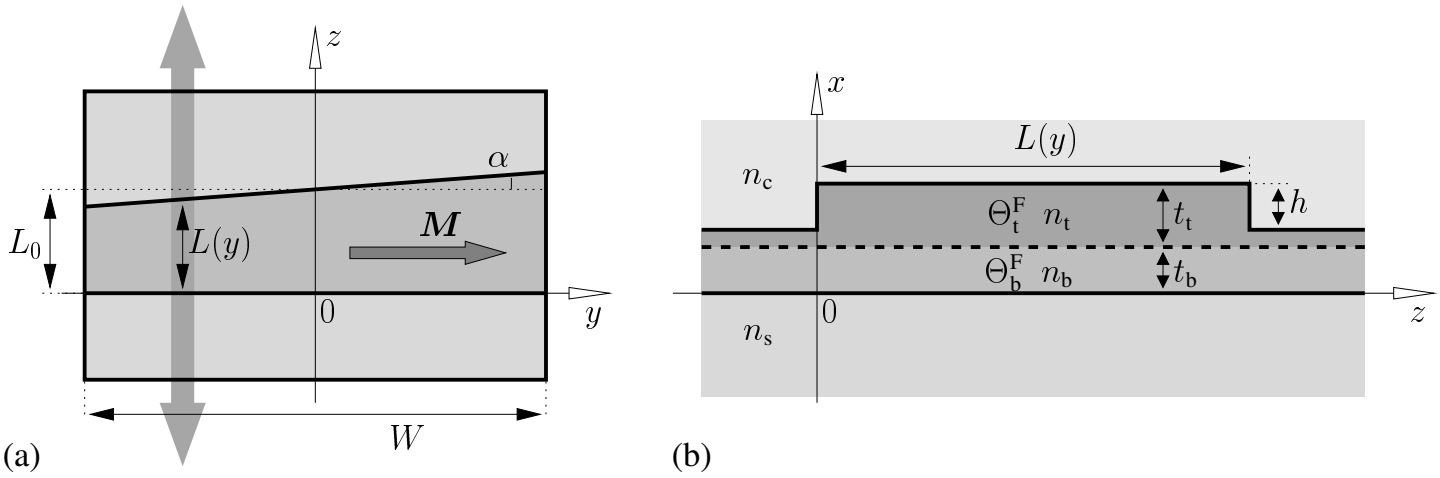


A strip made of magnetooptic garnet films . . .



. . . can behave like an optical isolator:





Magnetooptic garnet materials, permittivity:

$$\hat{\epsilon} = \begin{pmatrix} n^2 & 0 & 0 \\ 0 & n^2 & 0 \\ 0 & 0 & n^2 \end{pmatrix} + \begin{pmatrix} 0 & 0 & -\mathrm{i}\xi \\ 0 & 0 & 0 \\ \mathrm{i}\xi & 0 & 0 \end{pmatrix}, \qquad \xi = n\lambda\Theta^{\mathrm{F}}/\pi\,,$$

$W \approx 2\,\mathrm{cm}$, $\alpha \approx 0.05°$ Θ^{F}: specific Faraday rotation.

TM $\qquad \left.\begin{matrix} \overrightarrow{} \\ \beta_0^{\mathrm{f}}, \beta_1^{\mathrm{f}}, L_{\mathrm{c}}^{\mathrm{f}}, P^{\mathrm{f}} \end{matrix}\right\} \neq \left\{\begin{matrix} \overleftarrow{} \\ \beta_0^{\mathrm{b}}, \beta_1^{\mathrm{b}}, L_{\mathrm{c}}^{\mathrm{b}}, P^{\mathrm{b}} \end{matrix}\right.$

Isolator performance for $L = 2mL_{\mathrm{c}}^{\mathrm{f}} = (2m+1)L_{\mathrm{c}}^{\mathrm{b}}$ with natural m.

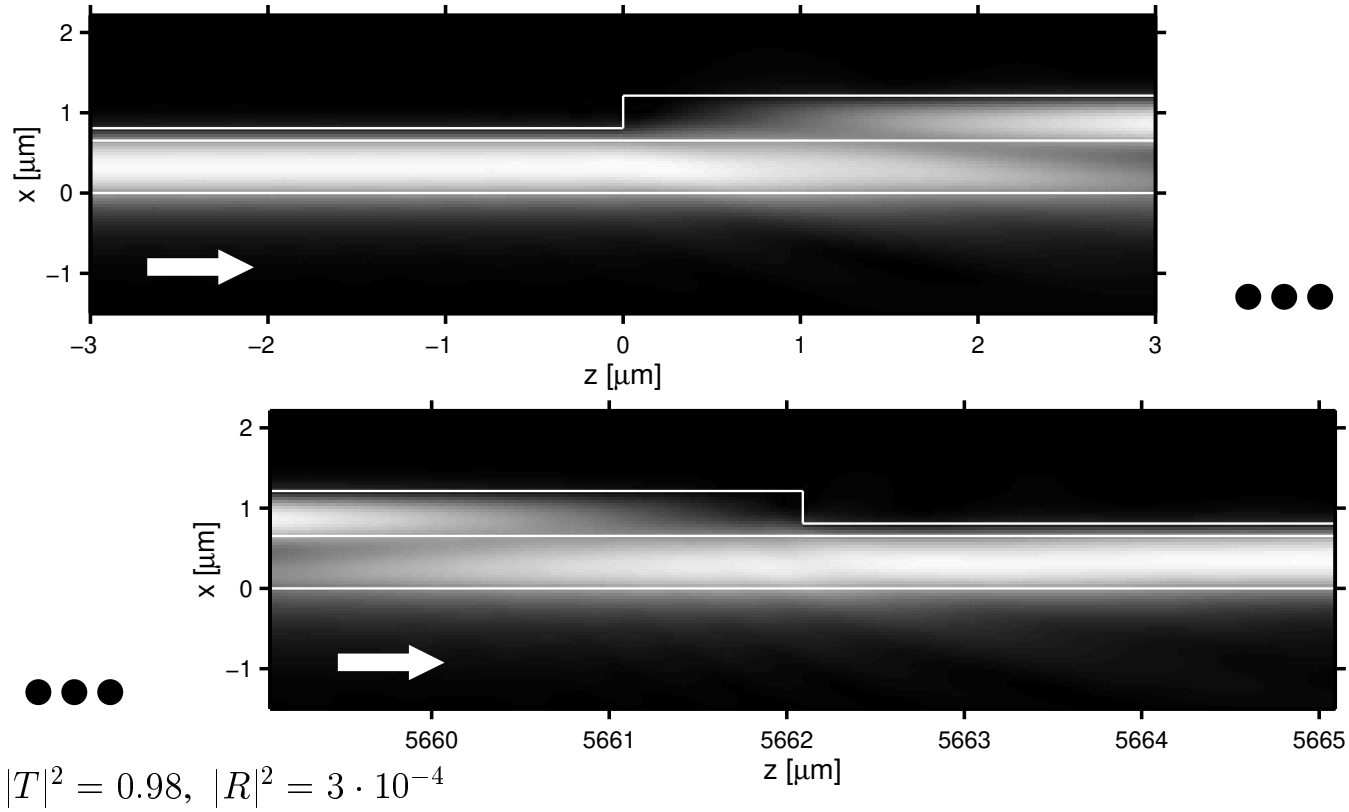
	q_0	Δq
t_{b}	$0.656\,\mu$m	$\geq 0.2\,\mu$m
t_{t}	$0.559\,\mu$m	$0.16\,\mu$m
h	$0.405\,\mu$m	30 nm
L_0	5.663 mm	1.6 mm
λ	$1.3\,\mu$m	≥ 90 nm

	q_0	Δq
n_{s}	1.950	0.1
n_{b}	2.157	0.02
n_{t}	2.275	0.02
n_{c}	1.0	≥ 0.4
$\Theta_{\mathrm{b}}^{\mathrm{F}}$	$150°/$ cm	$202°/$ cm
$\Theta_{\mathrm{t}}^{\mathrm{F}}$	$-1000°/$ cm	$360°/$ cm

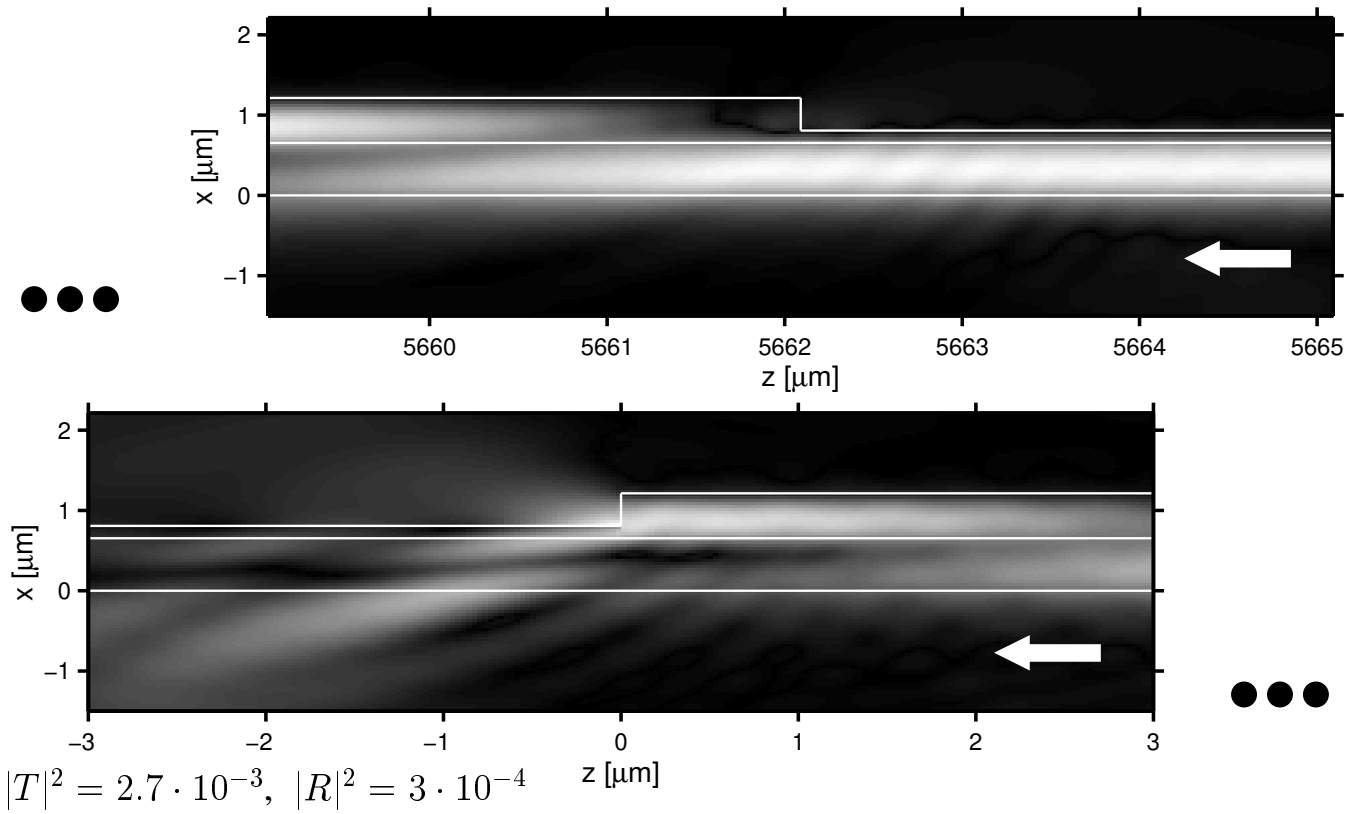
LO $= -10\log_{10} P^{\mathrm{f}}$, IS $= 10\log_{10} P^{\mathrm{f}}/P^{\mathrm{b}}$.

$q_0 - \Delta q \leq q \leq q_0 + \Delta q$: The experiment can be carried out with
IS ≥ 20 dB, LO ≤ 1 dB $\quad (P^{\mathrm{f}}/P^{\mathrm{b}} \geq 100,\ P^{\mathrm{f}} \geq 0.8)$.

$L_{\mathrm{c}}^{\mathrm{f}} = 4.5008\,\mu$m, $L_{\mathrm{c}}^{\mathrm{b}} = 4.4973\,\mu$m, $L_0/L_{\mathrm{c}}^{\mathrm{f}} \approx 1258$, $L_0/L_{\mathrm{c}}^{\mathrm{b}} \approx 1259$.

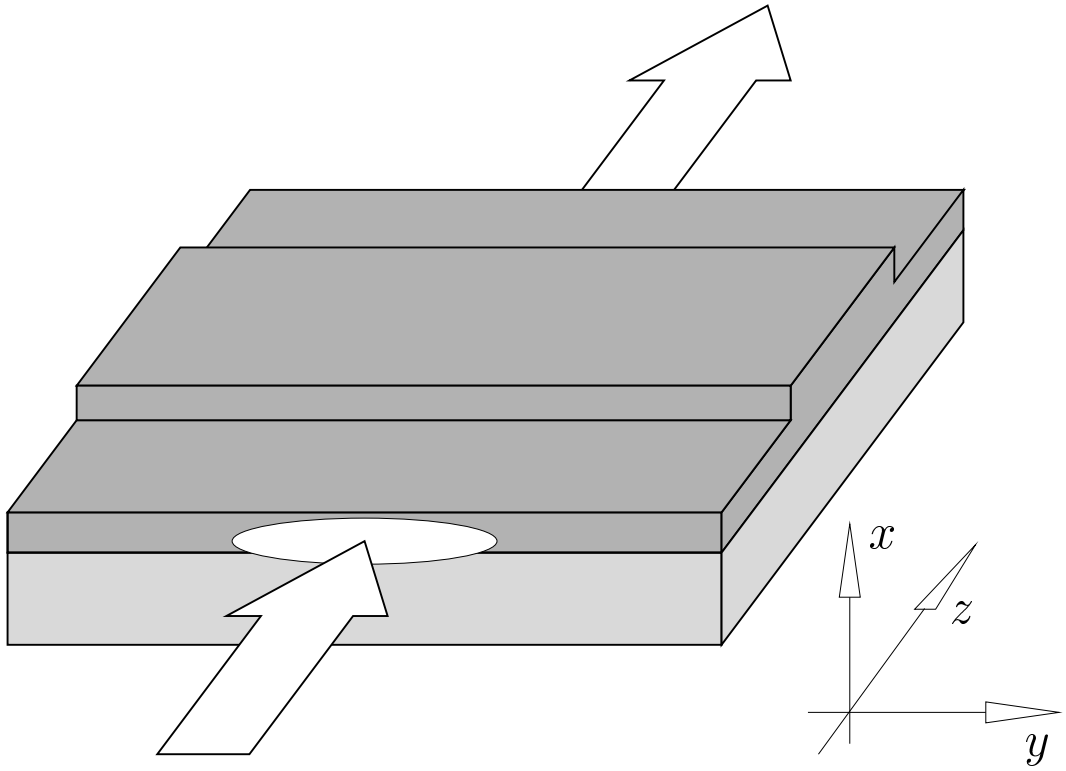


$|T|^2 = 0.98,\ |R|^2 = 3 \cdot 10^{-4}$



$|T|^2 = 2.7 \cdot 10^{-3},\ |R|^2 = 3 \cdot 10^{-4}$

$P^{\mathrm{f}} = 98\%,\quad P^{\mathrm{b}} = 0.3\%,\quad \mathrm{IS} = 26\,\mathrm{dB},\quad \mathrm{LO} = 0.1\,\mathrm{dB}.$



- Cross strip device: Something between
  - a directional coupler, and
  - a multimode interference device,
  - that can show excellent interferometer performance;

  in particular an explicitely *simple* structure.
- Applications include
  - polarizer devices, and
  - a concept for isolator experiments.