Integrated optical polarizer based on the cross strip interferometer configuration

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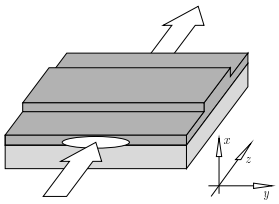
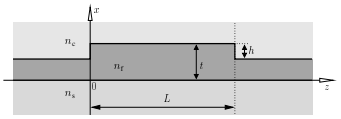
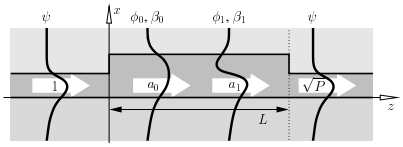
1 Cross strip interferometer

A bimodal segment of specific length and thickness between two single mode sections of a planar waveguide can serve as a simple interferometer. The configuration can be realized by etching a wide strip from a dielectric film and forcing a — vertically guided, laterally unguided — beam of light to traverse the strip perpendicularly. A TE-pass polarizer designed on the basis of this concept achieves more that 30dB polarization discrimination with a total length of only 5 micrometers, for air covered Silicon-Oxide/Nitride waveguides at a wavelength of 650 nanometers.





2 Overlap model



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,
$(\ldots)$: a suitable bilinear product.

Relative power transfer:

$$P(L) = w_0^2 + w_1^2 + 2w_0 w_1 \cos(\pi L / L_c) .$$

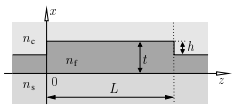
with $a_j = (\psi, \phi_j)$. $w_j = a_j^2$. $L_c = \dfrac{\pi}{\beta_0 - \beta_1}$.

L: the length of the thick section.

Modulation range of the transmission:

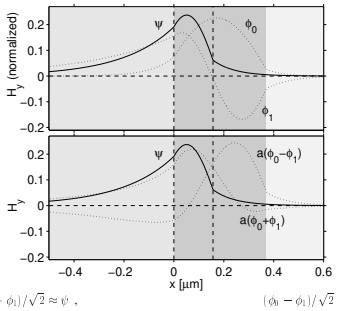
$$(w_0 - w_1)^2 \le P \le (w_0 + w_1)^2 .$$

3 Mode shapes



$t = 0.371\,\mu$m, $h = 0.214\,\mu$m,
$\lambda = 650$ nm, $n_s = 1.465$,
$n_f = 2.01$, $n_c = 1.0$.

TM polarization, basic magnetic field component H_y:

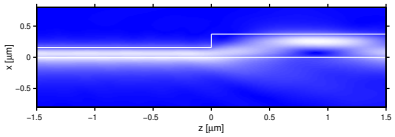


$(\phi_0 + \phi_1)/\sqrt{2} \approx \psi$, $(\phi_0 - \phi_1)/\sqrt{2} \perp \psi$.

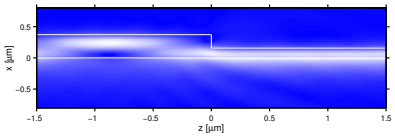
$a_j = 0.694$, $w_0 - w_1$, $(w_0 + w_1)^2 = 0.93$: $\min_L P = 0$, $\max_L P = 0.93$.

4 Interferometer performance

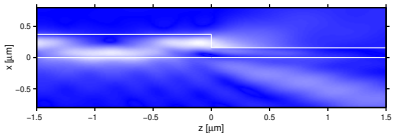
Low losses / reflections at the input junction:



Complete constructive . . .



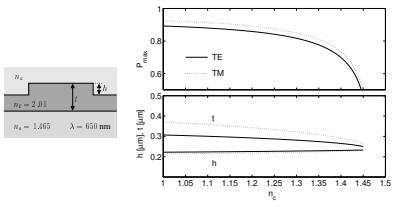
. . . or destructive interference at the output junction:



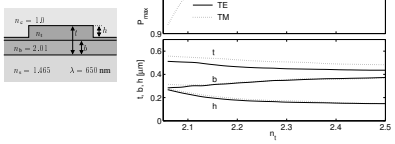
5 Optimized interferometer geometries I

Parameters with $w_0 - w_1$ and optimum $P_{\max} - (w_0 + w_1)^2$:

Single layer waveguide, variable cladding material



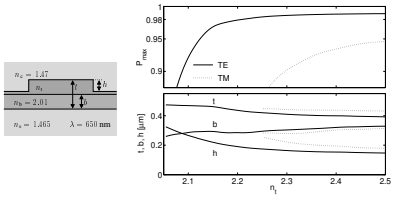
Double layer film, air cladding, variable top layer material



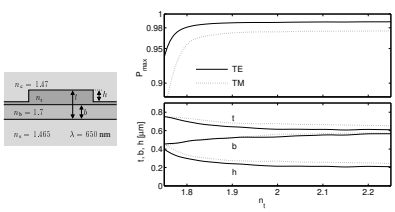
6 Optimized interferometer geometries II

Parameters with $w_0 - w_1$ and optimum $P_{\max} - (w_0 + w_1)^2$:

Double layer high index film, cladding, variable top layer material



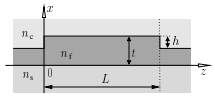
Double layer low index film, cladding, variable top layer material



7 Polarizer I

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

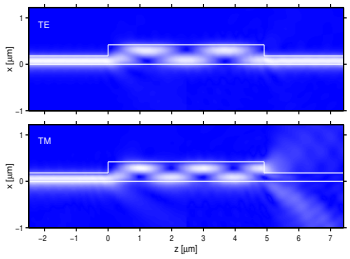
Single layer film



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

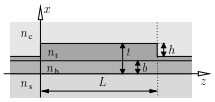
	t	b	h	L	λ	n_s	n_f	n_c
q_0	$0.420\,\mu$m		$0.240\,\mu$m	$4.910\,\mu$m	650 nm	1.465	2.01	1.0
Δq	4 nm		15 nm	50 nm	24 nm	0.011	0.015	0.04

$P^{TE} = 94\%$, $P^{TM} = 0.01\%$, ER $= 40$ dB, LO $= 0.3$ dB,
$L_c^{TE} = 1.227\,\mu$m, $L_c^{TM} = 0.98\,2\,\mu$m, $L = 4 L_c^{TE} = 5 L_c^{TM}$.



8 Polarizer II

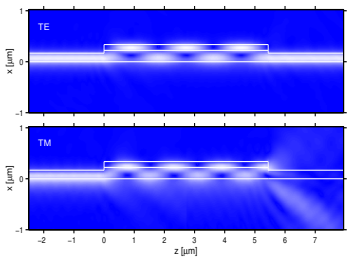
Double layer film, air cladding



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

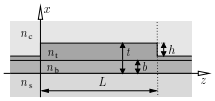
	t	b	h	L	λ	n_s	n_b	n_t	n_c
q_0	$0.337\,\mu$m	$0.222\,\mu$m	$0.169\,\mu$m	$5.441\,\mu$m	650 nm	1.465	2.01	2.3	1.0
Δq	14 nm	4 nm	10 nm	50 nm	11 nm	0.007	0.009	0.24	0.08

$P^{TE} = 97\%$, $P^{TM} = 0.06\%$, ER $= 32$ dB, LO $= 0.1$ dB,
$L_c^{TE} = 0.907\,\mu$m, $L_c^{TM} = 0.777\,\mu$m, $L = 6 L_c^{TE} = 7 L_c^{TM}$.



9 Polarizer III

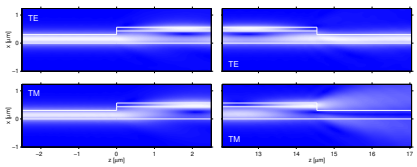
Cladded double layer film



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

	t	b	h	L	λ	n_s	n_b	n_t	n_c
q_0	$0.566\,\mu$m	$0.432\,\mu$m	$0.263\,\mu$m	$14.544\,\mu$m	650 nm	1.465	1.7	2.01	1.47
Δq	4 nm	2nm	43 nm	130 nm	14 nm	0.008	0.015	0.007	0.035

$P^{TE} = 96\%$, $P^{TM} = 0.003\%$, ER $= 46$ dB, LO $= 0.2$dB,
$L_c^{TE} = 1.818\,\mu$m, $L_c^{TM} = 2.078\,\mu$m, $L = 8 L_c^{TE} = 7 L_c^{TM}$.



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