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Versawave modulator schemes

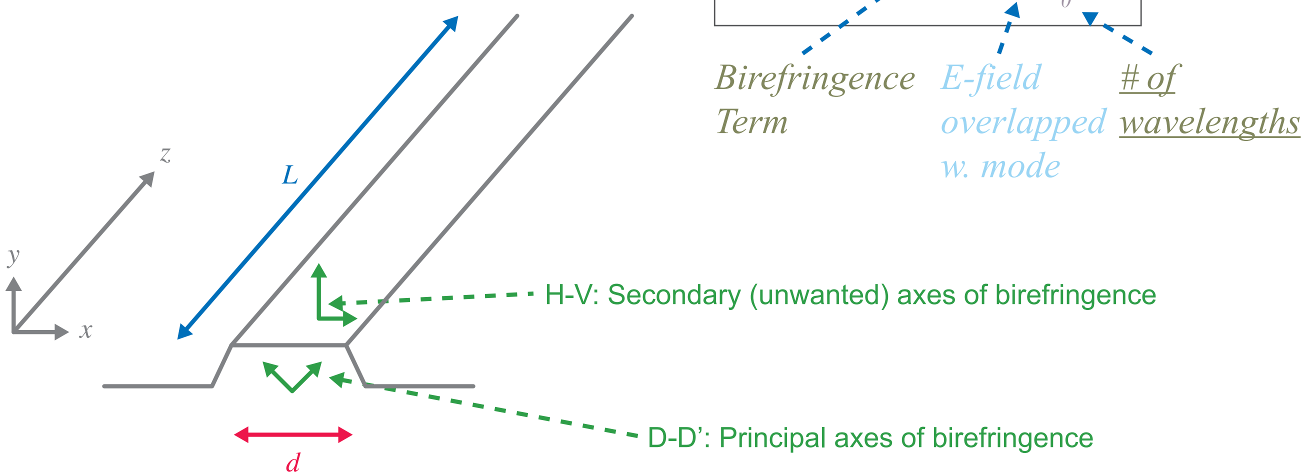
Basic device operation

The Versawave waveguide-geometry modulator chip has two principal birefringence axes oriented near 45 degrees to the wafer normal: the fast-axis eigenmode and the slow-axis eigenmode.
As voltage is applied to the device, the slow-axis eigenmode is retarded and the fast-axis eigenmode is accelerated in a push-pull configuration, due to the Pockels linear electro-optic effect from the corresponding E-field. Modulation can be achieved using a variety of schemes to exploit this birefringence as outlined below.

Waveguide geometry

Pockels biregringence equation

$$\varphi(z) = (\sqrt{3}n_0^{\,3}r_{41})\Gamma\,\frac{V}{d}\,\frac{z}{\lambda_0}\,\pi$$



One polarization - e.g. TE, converted by phase φ (z) over the Poincare sphere
For equal power in principal axes of birefringence:
$\varphi = \pi$ → TE converted to RCP or LCP (quarter-wave plate behaviour)
$\varphi = \pi$ → TE converted to TM

Modulation schemes

Polarization modulation

This is the core function of the device. Input light is either TE or TM, ensuring equal power to the two eigenmodes. As the voltage is increased the phase difference the slow-axis eigenmode relative to the fast-axis eigenmode increases. The superposition of the two eigenmodes along the length of the device induces a polarization change in the output light relative to the input polarization. As the voltage is increased the polarization goes through the Poincare sphere along a great circle which includes TE/TM and both circular polarizations. Travel around half the Poincare sphere is analogous to a variable waveplate going from zero to quarter-waveplate to half-waveplate behavior. Since the phase difference between the two equal-power eigenmodes is equal and opposite, there is minimal chirp.

Amplitude modulation

This is a follow-on application from the basic polarization modulation. If TE or TM input light enters the device and light exits the device followed by a TE or TM polarizer respectively, the TM or TE respectively in the output light is extinguished. So for Vpi there is no amplitude. As the voltage is increased the output light amplitude goes from a max to a min to a max as the polarization follows the great circle of the Poincare sphere from TE to TM back to TE. A variation of this scheme is to have the output polarizer be the opposite of the input polarization (e.g. TM output polarization for TE input light, or vice versa). In that case, the min occurs for zero voltage.

Linear polarization modulation

This is a sophisticated follow-on application from polarization modulation. Just like for polarization modulation, input light is TE or TM, ensuring that half the power goes to each eigenmode and the device functions like a polarization modulator with arbitrary polarized output (usually elliptical) for arbitrary voltage. The output light exits the device followed by a quarter-wave plate with principal axes also oriented TE and TM. This has the effect of undoing the phase retardation which caused elliptical polarization and converting the arbitrarily (usually elliptically) polarized light to a linear polarization. As voltage increases the polarization goes through the Poincare sphere along the great circle restricted to linear polarizations – i.e. the linear polarization axis rotates as the voltage is increased.

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