

A Hitchhiker's Wave Guide to Photonic Chips

Physics, fabrication, and the road to volume

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Summary:

Evanescent field sensing enables the measurement of small refractive index changes at the interface of a planar optical waveguide and its surface coating. It has been researched in academic environments for the past 30 years. One of the recently emerging technologies is Grating-coupled Interferometry (GCI), which enables label-free, real-time analysis of molecular interactions at surfaces.

A key challenge of this technology is the fabrication of waveguide coatings and Grating Couplers at scale. This work shows how we, IMT Masken und Teilungen AG, produce glass-based coplanar waveguide chips in volume, leveraging wafer-based manufacturing techniques of the semiconductor industry. In particular, the in-house developed characterization method will be emphasized.

Keywords: Waveguide, Evanescence, Lithography, Glass, Grating

Background, Motivation and Objective

Evanescent field sensing brings together interesting branches of photonics technology. The main pillar is the sputter coating of a planar waveguide materials and surfaces. Second, light needs to enter the waveguide in some convenient way. This is achieved by fabricating phase gratings with submicron feature sizes, which requires a firm grip on lithography processes. I will provide an overview of the underlying physics and shine light on what challenges we were facing, bringing such technology to a scale of a few thousand chips per batch.

For waveguiding microchips leaving production, not only the structural specification must be met, but also the optical functionality must be verified. Therefore, we developed a custom-built measurement setup that allows for the optical characterization of the waveguide chips.

Description in-house developed characterization tool.

Our wafer-based inspection tool (Fig. 1) consists of rotating motorized axes with Laser, Diodes, Cameras and an XY-Stage in its center.

We know the total light power P_{tot} introduced into a grating coupler via reference diode. Furthermore, we measure transmitted and reflected power P_T and P_R via diodes on the two rotary arms.

$$P_{\text{tot}} = P_T + P_R + P_{\text{Scatter}} + P_{\text{Couple}} \quad (1)$$

Neglecting diffusely scattered power loss $P_{\text{Scatter}} \approx 0 \text{ W}$ enables measurements of grating coupler efficiency, expressed as a fraction of coupled light power to total light power $P_{\text{Couple}}/P_{\text{tot}}$. This is an interesting property for the final sensing application. The amount of light power coupled into the system directly affects signal-to-noise ratio and sensitivity in the application our chips are part of.

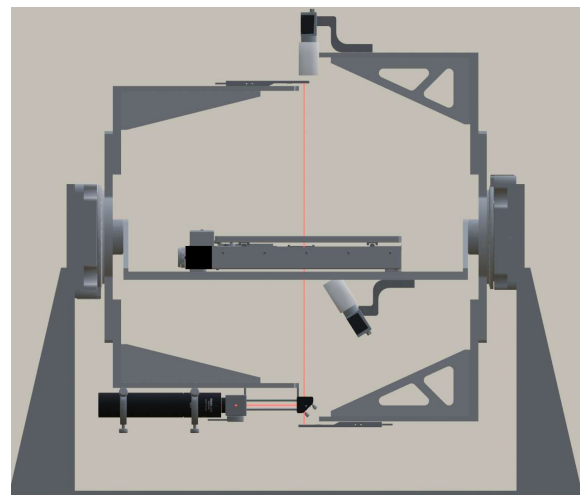


Fig. 1. Sketch of our R&D-built measurement setup for Waveguide and Grating Coupler characterization.

One camera is installed close to the waveguide surface ($< 5 \text{ cm}$, below the stage). With that, we can get a good estimate of the attenuation of our coatings by analyzing the decay of scattered light within the waveguides.

Results

In Fig. 2, an example for a coupling curve of a typical waveguide can be seen.

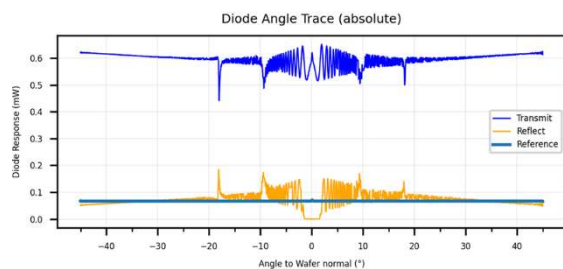


Fig. 2. Diode Angle Trace of a typical grating Coupler for visible light Evanescent sensing.

The grating coupler exhibits birefringence, that is, a polarization dependence on the refractive index. Therefore, we can find two resonances, “Coupling Angles” in positive and negative direction. Those are commonly referred to as TM and TE modes. Once the coupling angles are analyzed and considered proper, the system can be driven to the desired angle and light of the desired polarization will be coupled into the coating. Subsequently, scattered light along the incident beam can be analyzed with a scattering camera (see Fig. 3).

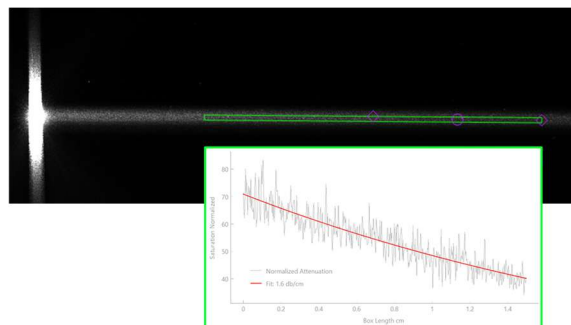


Fig. 3. Attenuation Analysis. With a length-calibrated camera image, the decay constant is given as $\alpha = 1.6 \text{ db/cm}$.

The decay of the signal within the coating is calculated within a Region of Interest (ROI, green box). Due to imperfections within the amorphous Ta_2O_5 layer, we can observe the decay of the signal as “scatter light” along the incident beam.

We can describe its exponential decay with the definition of optical attenuation $I(x) \sim 10^{-\alpha \cdot x/10}$, resulting in the given value of 1.6 db/cm .

In close collaboration with our customers, we are constantly improving our manufacturing processes to produce the highest possible refractive indices with lowest possible attenuation.

References

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