Lab-on-a-Chip: Direct coupling of light into a planar thin film waveguide

As disposable products, waveguide-based biochips offer a wide of possibilities, but relatively high manufacturing costs often make their use uneconomical. The most important cost factor is the structuring of the chip, which enables effective coupling of the laser light. A novel coupler makes it possible to couple light into chips without structuring.

Challenge

Planar thin film waveguides have become indispensable tools in various fields such as telecommunication technology, biosensors and material characterization. In biosensor technology, for example, they can be used to efficiently excite dye molecules and to follow changes in the surface coating extremely precisely. A decisive point in the use of waveguide-based biochips is the coupling of the laser beam into the waveguide.

Due to the low layer thickness and the high refractive index, coupling via the end surface of the waveguide or prism coupling is not feasible.
The only practical method to date is light coupling via so-called grating couplers, i.e. gratings with periods in the sub-micrometer range that are structured in the waveguide using an etching process. This grating is responsible for a large part of the costs used to manufacture the chip. Since biochips are generally disposables, a cost reduction is very interesting here.

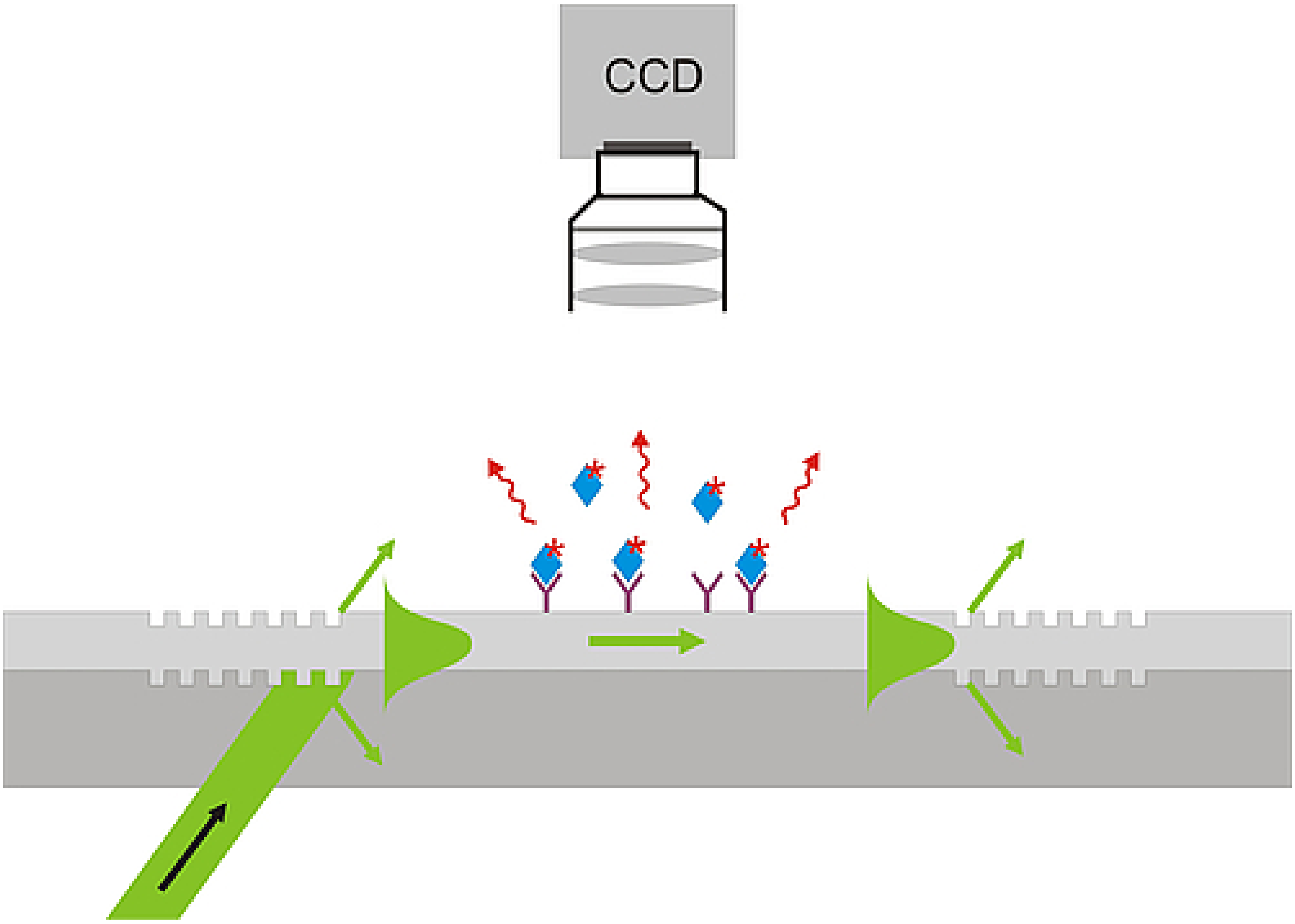

Figure 1: Function principle of evanescence field microscopy: The light of a laser is coupled into a microscope slide via a grating structure. The evanescent field stimulates optical transitions in molecules located on the surface of this carrier. (Source: Fricke-Begemann)

Our Solution

With the coupler presented here, the grating for coupling the light is not first structured on the chip, but already on the light feed line. For this purpose, the light of a light-guiding fiber is expanded and collimated with the aid of a GRIN lens. The second end face of this lens is structured in the form of a grating, which induces the modulation of the refractive index necessary for coupling in this waveguide when it is close to the actual waveguide surface. To adjust the coupling angle, the structured end face can be ground at a defined angle. A GRIN lens, a rod lens or - with previous collimation - a simple glass or quartz cylinder can be used for collimation

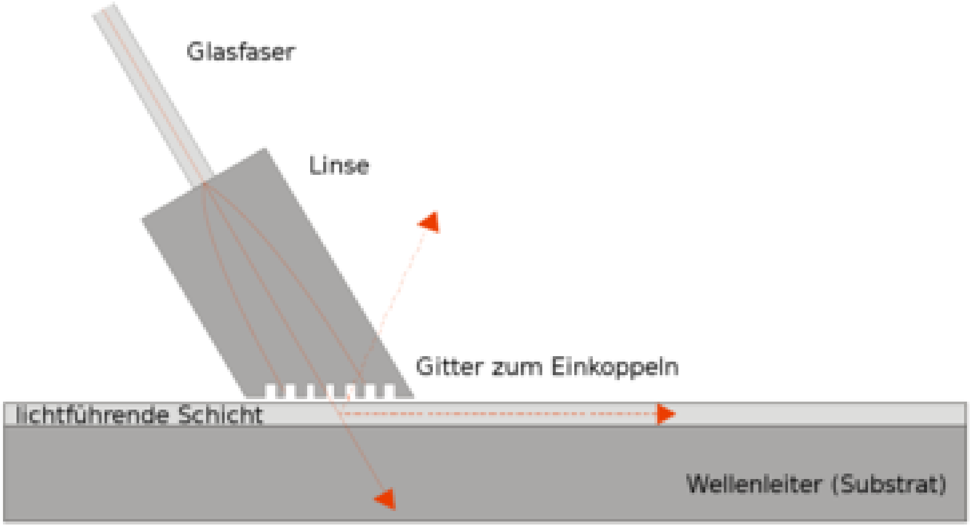

Figure 2: Functionality of the simplified structure: The light is guided via a glass fibre to a lens. This is ground on the side facing the waveguide and provided with a grating. This means that the grating no longer has to be applied to the light-conducting layer of the waveguide. If there is sufficient proximity between the grating and the waveguide, the laser light is coupled in. (Source: Fricke-Begemann)

Advantages

- significantly reduced costs for the production of a biochip
- greater flexibility in the production of the chip surface, since the grid is no longer a limiting factor
- cost-effective production of sample carriers for TIRF microscopes (internal total reflection fluorescence)

With the use of waveguides as sample carriers, an evanescence field excitation can also be performed on any microscope (including simple, appropriately retrofitted microscopes). Highly specialized TIRF microscopes and special objectives are no longer required.

Applications

- biochips (lab-on-a-chip)
- evanescence field investigations
- material tests
- sample carrier for internal Total Reflection Fluorescence Microscopy (TIRFM)

Developmental Status

In order to be able to estimate the achievable coupling efficiency, simulations were carried out with which it could be shown that, in principle, efficiencies of up to 40% can be achieved with a given coupling length.
For a first experimental realization, the end surface of a GRIN lens was structured with a 500 nm grating. In contact with the waveguide, a coupling efficiency of 13.4% could already be demonstrated.

Patent Status

Granted German patent: DE102010029612 (B4)
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