Amplification of the diffraction angle for non-mechanical LIDAR scanner

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Spatial light modulators (SLM) and optical phase delay arrays (OPDA) are particularly interesting for light beam steering since they are a non mechanical way of achieve this function. As such, they are not prone to mechanical failure due to fatigue, they are faster, lighter, and more compact than other techniques. These advantages make SLM/OPDA attractive for applications such as optical switching, free space optical communication, and LIDAR.

However, the maximum diffraction angle that can be achieved by an SLM/OPDA, is governed by Bragg's law, and is limited to a few degrees given the current pixel pitch (4µm pitch at 1550nm = 5.5° angle). For some applications such as FSO, or LIDAR, this angle is not large enough. The angle is even smaller when using the more efficient blazed grating configuration that uses more pixels to define their saw-tooth profile.

To amplify the angle at which the beam is diffracted, it is possible to use a simple lens. However, in this case, the beam not collimated anymore, it is diverging. To keep the beam collimated, a second lens is needed to form a telescope. Unfortunately, this configuration is bulky and the field of view is substantially restricted.

To keep the form factor very compact, and to achieve 2π steradian coverage, we have devised a solution based on multiplexed volume holograms. Volume, or Bragg, hologram are permanent diffractive structures that are highly selective according to the light incidence angle. Volume holograms diffract the light that is incident at a very specific angle (pre-defined), but let the light coming at other angles passing through unaffected (see figure 1).

The sensitivity of the diffraction efficiency according to the incident angle can be calculated by the coupled wave analysis to determine the correct parameters for the hologram (see figure 2). In a nut shell, the thicker the hologram, the more selective it is. Hologram a few millimeters thick can be made sensitive to a fraction of a degree.

In addition, multiple holograms can be recorded within the same material. This is called volume multiplexing, and it has been used in holographic data storage for many years. Hundreds of thousands of holograms within the same location has been demonstrated. Using this technique, each incident angle, diffracted by the SLM/OPDA, can be redirected, uniquely, by the volume hologram to a much larger angle. This configuration literally amplifying the original angle.

Since all the holograms are recorded within the same volume, the diffractive element has the form factor of a sheet of material that can be directly overlaid on the top of the SLM/OPDA, keeping the system extremely compact.

Using the same system along with a hemispherical lens, it is even possible to retro-reflect the beam behind the SLM/OPDA, and to cover up to 4π steradian (see figure 3).

A patent application has been filed explaining the system:

P.-A. Blanche, "Expansion of angular distribution of a light beam to cover up to 4pi steradian".

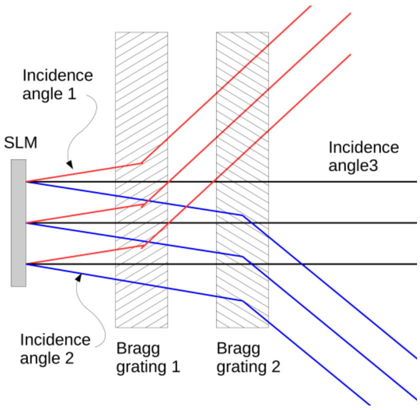

Figure 1: Volume Bragg gratings redirect different incidence to larger angle leaving other angles unaffected. In the best configuration, the gratings can be multiplexed and directly overlaid on top of the SLM.

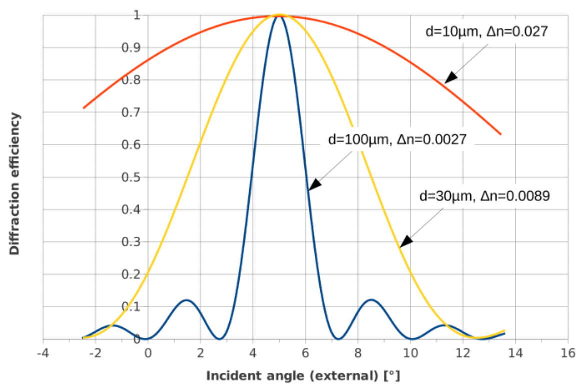

Figure 2: Coupled wave analysis computation of the efficiency of several volume holograms according to the incidence angle. Note how the angular selectivity get stronger when the hologram get thicker.

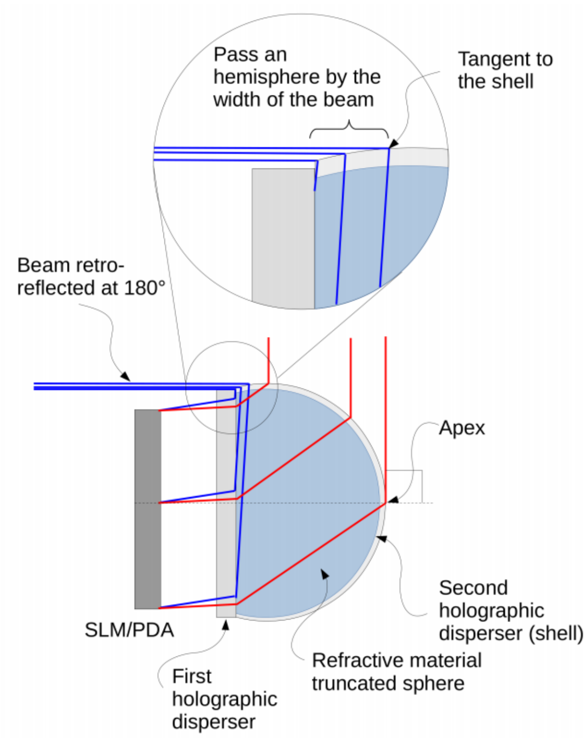

Figure 3: Using an hemispherical lens to achieve retro-reflection and to cover 4π steradian field of view.