Polarizing properties of sapphire and gadolinium-gallium garnet cells used in Na Faraday anomalous dispersion optical filter

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The Na resonance scattering lidar is a laser sensing system that uses the resonance scattering of Na atoms distributed in the mesosphere and lower thermosphere. To improve the signal-to-noise ratio (SNR) of such lidar observations, an ultra-narrowband filter for largely reducing the background noise could be an effective upgrade, and in the case of Na lidar, the Na Faraday anomalous dispersion optical filter (FADOF) may be available. The principle of Na FADOF is based on the magneto-optical properties of the Na atoms, and it limits transmission wavelength by controlling the polarizing angle of the incident light. For this operation, the Na FADOF consists of two crossed linear polarizers and a Na vapor cell placed between them, under the conditions of high magnetic fields and high temperatures. The Na vapor cell is normally made of silica-based glass, and thus chemical reactions of the glass and alkali vapor, such as Na vapor, can be a big problem in such high-temperature environments. To solve this problem, chemically stable cells are needed, instead of silica-based glasses. For this reason, sapphire and gadolinium-gallium garnet (GGG) cells are suggested. The sapphire and GGG are well known to be chemically stable against high-temperature Na vapor. On the other hand, the polarizing properties of sapphire and GGG are not so clear, and hence these should be clarified for an application to Na FADOF operation.

In this study, we have quantitatively evaluated the polarizing properties of sapphire and GGG, based on experiments. In the experiments, a linear polarizing laser is used as an incident light to sapphire and GGG, and then the polarizing properties of the transmitted light through the sapphire and GGG are measured in the cases of several incident angles. In particular, we focus on two parameters: (1) how much of the linear polarizing component is maintained without power loss, and (2) how much of the polarizing angle is maintained without rotation, compared with those in the case of no material, i.e., in the cases without sapphire or GGG. The obtained results are followings. As for the sapphire, in the cases of the incident angles of less than 6°, 84-94% of the linear polarizing components were maintained, and the changes in the polarizing angle were less than 0.2°. On the other hand, both parameters were highly variable (or not so maintained) in the cases of larger incident angles. Hence, it would be difficult to use the sapphire for Na FADOF in the cases of such larger incident angles. As for GGG, both parameters were less dependent on the incident angle. Specifically, 80-85% of the linear polarizing components were maintained, and the changes in the polarizing angle were less than 6°. Based on these results, it would be considered that GGG can be useful for wider FOV applications, such as imaging observations. On the other hand, sapphire would be a more appropriate candidate (with smaller power loss) for narrower field-of-view (FOV) applications, such as lidar observations, in which the incident angle is less than 6°.

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