On-chip ultra-low-loss chalcogenide glass optical waveguides and resonators for mid-infrared photonics

Hansuek Lee*

Department of Physics, Korea Advanced Institute of Science and Technology (KAIST); Daejeon, 34141, South Korea

**E-mail:hansuek@kaist.ac.kr*

The mid-infrared wavelength region, where fundamental absorption bands of various molecules exist, is of great importance for many applications to monitor and manipulate molecules such as molecular sensing, biochemical imaging, time-resolved spectroscopy, and photochemical processing. As an ideal material platform in the mid-IR, chalcogenide glasses (ChGs) have attracted much attention due to their high transparency and large optical nonlinearity in contrast to conventional on-chip optical materials such as silica and silicon nitride which suffer from significant losses due to multiphonon absorption [1]. However, the loss of on-chip ChG components has remained significantly higher than that of the optical fiber form, preventing the full exploitation of their inherent large optical nonlinearities on a chip in the mid-IR.

In this talk, we present on-chip ChG resonators with Q-factors larger than 60 million, exceeding previous records in the mid-IR by more than 60 times [2, 3]. The corresponding optical loss of 0.29 dB/m matches that of ChG fibers drawn from the same material source, indicating that our platform has reached the material-absorption limit. At these exceptionally low losses, we detect prominent absorption bands linked to molecular vibrations of internal impurities, underscoring the importance of impurity management for further reducing mid-IR loss. By exploiting this ultra-high Q-factor together with the controllability of free spectral range provided by microfabrication, we have successfully demonstrated Brillouin lasing in this wavelength region for the first time. Our results exhibit a threshold power of 0.1 mW and a Schawlow-Townes linewidth of 85 Hz, significantly surpassing that of commercialized quantum cascade lasers [3]. We will also discuss future research opportunities enabled by cavity-enhanced strong interactions between light and molecules, such as molecule-induced nonlinear optics and vacuum field catalysis [4].

References

[1] Benjamin J. Eggleton, Barry Luther-Davies, and Kathleen Richardson, "Chalcogenide Photonics," *Nature Photonics*, vol. 5, pp. 141-148, 2011

[2] Dae-Gon Kim, Sangyoon Han, Joonhyuk Hwang, In Hwan Do, Dongin Jeong, Ji-Hun Lim, Yong-Hoon Lee, Muhan Choi, Yong-Hee Lee, Duk-Yung Choi, and Hansuek Lee, *Nature Communications*, vol. 11, 5933, 2020

[3] Kiyoung Ko, Daewon Suk, Dohyeong Kim, Soobong Park, Betul Sen, Dae-Gon Kim, Yingying Wang, Shixun Dai, Xunsi Wang, Rongping Wang, Byung Jae Chun, Kwang-Hoon Ko, Peter T. Rakich, Duk-Yong Choi, Hansuek Lee, *Nature Communications*, vol. 16, 2707, 2025

[4] Seong Cheol Lee, Soobong Park, Daewon Suk, Joonhyuk Hwang, Kiyoung Ko, Won Bae Cho, Duk-Yong Choi, Kwang-Hoon Ko, Fabian Rotermund, and Hansuek Lee, *APL Photonics*, vol. 9, p. 080802, 2024