Layered MoS_2 for the enhancement of supercontinuum generation in photonic crystal fiber

Xu Cheng[1,2], Jin Xie[3], Guodong Xue[3], Hao Hong[3], Zhipei Sun[2], Kaihui Liu[3], Zhongfan Liu[4,5]

[1] *Group for Fibre Optics, École Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland*

[2] *QTF Center of Excellence, Department of Electronics and Nanoengineering, Aalto University, Espoo, Finland*

[3] *State Key Laboratory for Mesoscopic Physics, School of Physics, Peking University, Beijing, China*

[4] *Center for Nanochemistry, College of Chemistry and Molecular Engineering, Peking University, Beijing, China*

[5] *Beijing Graphene Institute (BGI), Beijing, China*

khliu@pku.edu.cn

1. Introduction

Decorating the silica-based photonic crystal fibre (PCF) to enhance its nonlinearity and expand its spectrum range is a significant research topic in supercontinuum laser optics [1]. Previously, methods such as filling nonlinear gases or liquids into the hollow core PCFs have been explored and made great progress [2], yet these hybrids are plagued by mode instability, leakage risk and environmental fluctuation. The emergence of two-dimensional (2D) layered materials offers a unique opportunity. The integration of 2D robust crystals could ensure the stability and portability of PCF for table-top laser sources. Here, we report the first realization of integrating solid-state 2D nonlinear optical layers with commercial nonlinear PCF to boost its supercontinuum generation (SCG) efficiency.

2. Result and discussion

For SCG in the PCF, the transmission loss, dispersion profile and nonlinear coefficient are the three most important parameters. In principle, 2D layered MoS_2, with the merits of atomic-level flatness and relative large bandgap (with low scattering loss and absorption), extremely thin thickness (hardly damage the transmission mode and dispersion profile of optical fiber), ultra-high optical nonlinear response (n_2 is about 5 orders of magnitude higher than that of silica at 1550 nm), and facile integration with silica-based waveguides, is an ideal partner to combine with PCF for its SCG enhancement [3,4]. Guided by these inspirations, here we directly grow solid-state thin-layer 2D MoS_2 into the air-holes of nonlinear PCF (MoS_2-PCF) and investigate its SCG performance (Figure 1). As expected, the SCG of the MoS_2-PCF exhibits a significantly enhancement compared with that of the bare-PCF. Specifically, the threshold power to reach one octave broadening in the MoS_2-PCF is reduced by 30% compared to that of the bare-PCF. This improvement of SCG efficiency mainly originates from the enhancement of the nonlinear coefficient by the interaction of the optical field with MoS_2.

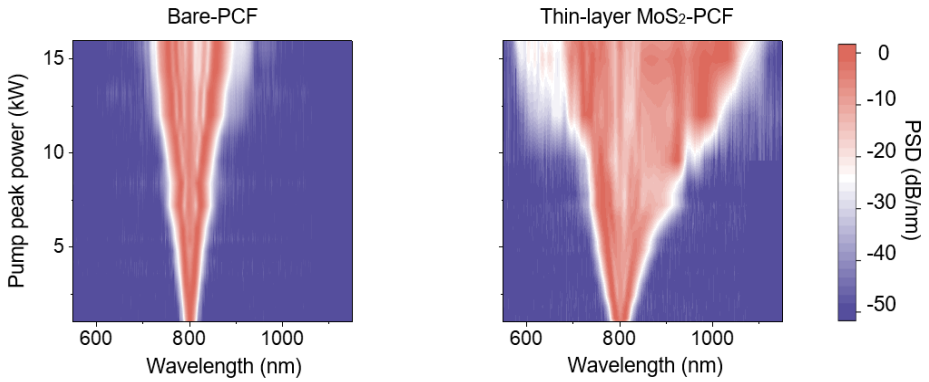

Fig. 1 SCG spectral evolution profiles of the bare-PCF (left) and thin-layer MoS_2-PCF (right) under 800 nm pulsed laser pump. The embedded thin MoS_2 film enhances the SCG broadening significantly.

3. Conclusions

To the best of our knowledge, our work should be the only feasible route of integrating a solid-state nonlinear optical crystal with PCF to enhance its SCG. Given the large library of 2D materials with diverse physical properties, this non-destructive, portable and easy-to-integrate solution will greatly promote the development of fiber-based table-top light sources with different functionalities.

4. References

[1] R. R. Alfano, *The supercontinuum laser source: the ultimate white light* (Springer, 2022).

[2] J. M. Dudley, G. Genty, S. Coen, Review of Modern Physics, **78**, 1135 (2006).

[3] A. Autere, H. Jussila, Y. Y. Dai, Y. D. Wang, H. Lipsanen, Z. P. Sun, Advanced Materials **30**, 1705963 (2018).

[4] Y. G. Zuo, W. T. Yu, C. Liu, X. Cheng, R. X. Qiao, J. Liang, X. Zhou, J. H. Wang, M. H. Wu, Y. Zhao, P. Gao, S. W. Wu, Z. P. Sun, K. H. Liu, X. D. Bai, Z. F. Liu, Nature Nanotechnology **15**, 987 (2020).