Gas flow in hollow-core photonic bandgap fibers

Jes Henningsen, Niels Bohr Institute
Jan Hald, Danish Fundamental Metrology

The development of hollow-core photonic bandgap fibres has paved the way for a novel class of experiments on the interaction between light and gases, in which it is possible at the same time to maintain a high optical intensity and a long interaction path. However, for experiments in which the gas has to be interchanged, a practical limitation is the time required for filling or venting the fibre.

We have studied the dynamics of gas flow in the core over four decades of pressure, ranging from conditions of free molecular flow, where the mean free path between mutual collisions is much longer than the core diameter, to the hydrodynamic regime, where the opposite is the case. In both limits the dynamics of filling and venting can be derived from universal functions by appropriate scaling of the time axis. In the free molecular flow limit the scale factor is indpendent of pressure, leading to a perfect symmetry between filling and venting. In the hydrodynamic regime the scale factor is inversely proportional to pressure, and as a consequence venting takes longer than filling.

The results are validated by experiments on acetylene, using absorption lines in the 1530 nm region as pressure probes, and excellent agreement is found for a range of fibre parameters outside an intermediate pressure range of Knudsen flow, where neither limit applies.