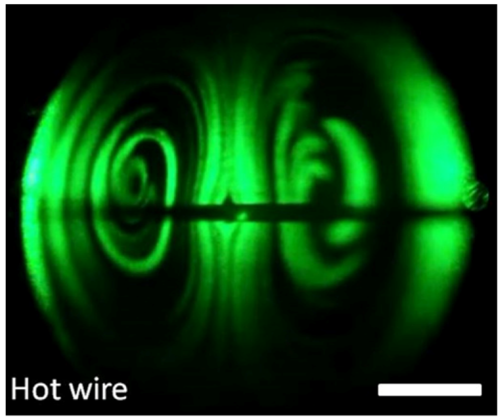

Fig. 4. Vortex pair formed in the glass tube with 14 mm in diameter created by a hot resistance wire, which casts a horizontal shadow. The temperature of the wire was adjusted to match the period of rotation of the laser-induced vortices. The scale bar is 3mm.

The measurements presented here are useful for implementation of applications based on laser filaments. For single pulse applications, the laser experiences no distortion from local heating as it propagates. However, the fluid flow dynamics in the wake of the pulse are disturbed by local heating. We are aware of one type of measurement whereby a femtosecond laser excites the excited B-state of nitrogen, and the emission is used to achieve molecular tagging velocimetry (MTV) [20] for fluid dynamics studies in air [9]. Findings of local heating introduced by a filament and the changes in fluid dynamics surrounding the filament suggest that MTV experiments need to take these effects into account and care must be exercised in the interpretation of results. Conversely, the findings reported here indicate filaments can be used to affect fluid flow dynamics remotely.

5. Conclusion

We report on the experimental observation of fluid flow caused by propagation of femtosecond filaments in dry air. Significant flow disturbance comprising multiple vortices has been observed. We hypothesize that the nature of this fluid flow arises from gas expanding from the heated region created by the plasma associated with filamentation. Convection processes and the constrained volume force the gas to form vortices. This hypothesis has been tested with a heated wire placed in the tube instead of laser beam, and the observed vortex formation was very similar to the laser-induced one. These findings confirm the importance of heat flux from filaments and the resulting fluid flow, a result relevant to applications of filaments for molecular tagging velocimetry, condensation and in general for the use of high-repetition rate sources where the medium does not renew fast enough and subsequent pulses travel in areas with increasing thermal energy. The analysis presented explains the simplest case of a single pair of vortices induced by an updraft caused by thermal buoyancy. Under certain conditions of intense laser excitation and confinement more complicated fluid flow is observed. We plan to explore the higher energy regime, and different chamber configurations using axial as well as transverse light sheet illumination.

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