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Generation of arbitrary axisymmetrically polarized pulses with a broadband spectrum using Pancharatnam–Berry phase

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An axisymmetrically polarized (AP) mode, a kind of the cylindrically polarized modes or the vector vortex modes, has the symmetry of C_∞ in both the polarization and the intensity distributions. The high symmetry of the AP modes with polarization singularity as well as optical vortices (OVs) with the phase singularity, has attracted much attention for the various research topics such as super-resolution microscopy, particle acceleration, laser processing and optical tractor. Recently, some applications using ultrashort or broadband AP pulses have been reported such as quantum communication, generation of extreme ultraviolet AP beams, and nonlinear spectroscopy. In order to fully explore the potential of the AP modes, it is crucial to develop a generation system of ultrashort and/or ultra-broadband AP pulses, while there are fewer researches on the generation of AP pulses in comparison with the generation of AP continuous wave beams. In addition to the generation of ultrashort and ultra-broadband OV pulses (pulse energy: several tens of μJ) in few-cycle regime, we have already reported on the generation of AP broadband pulses by using the combination of a spatial light modulator (SLM) in the 4-*f* configuration and a coherent combining system, and showed that the arbitrary AP states can be generated by superposing the left and right circularly polarized OV broadband pulses. Thanks to the 4-*f* configuration SLM (4-*f* SLM), this method enables us to modulate the complex amplitude distribution in the radial axis of AP broadband pulse beams. However, a separate-path combiner in the coherent combining system, being sensitive to disturbance (e.g. vibration and air turbulence), causes a practical issue. In the present paper, we demonstrate the generation of arbitrary AP pulses with spatial complex amplitude modulation by the system composed of a 4-*f* SLM, polarization converter and a space-variant wave plate (SVWP). Here polarization converter is composed of two achromatic half-wave plates and an achromatic quarter-wave plate. This scheme brings arbitrary Pancharatnam–Berry phases on pulses by rotating achromatic half-wave plates that sandwich an achromatic quarter-wave plate. This method is robust over disturbance thanks to a SVWP constituting a common-path beam combiner, supporting broadband pulses because the 4-*f* SLM compensates for the spatial chromatic dispersion. The combination of the 4-*f* SLM and the SVWP gives the complex amplitude modulation in all the directions without chromatic dispersions for not only linear polarization states but AP states. Moreover, we evaluate the properties of the AP pulses qualitatively and quantitatively through their interference fringe pattern with a reference and extended Stokes parameters, respectively.

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