Orbital-angular-momentum-preserving helical Bloch modes in twisted photonic crystal fiber: supplementary material

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An eigenmodal analysis of the structure in Fig. 1(a) in the primary article follows from the matrix equation:

$$\begin{pmatrix} \mathcal{G} & \kappa_2 & \kappa_2 & \kappa_2 \\ \kappa_2 & 0 & \kappa_1 & \kappa_1 \\ \kappa_2 & \kappa_1 & 0 & \kappa_1 \\ \kappa_2 & \kappa_1 & \kappa_1 & 0 \end{pmatrix} \begin{pmatrix} a_0 \\ a_1 \\ a_2 \\ a_3 \end{pmatrix} = (0) \quad (\text{S1})$$

for the amplitudes of the fields in the four cores. The satellite cores couple to each other at rate κ_1 and the central core is coupled to and dephased from the satellite cores at rates κ_2 and $\mathcal{G}$. Solving Eq. (S1) reveals that two non-degenerate even and odd modes are supported, with fields peaking in the central core and equal in-

phase amplitudes in the satellite cores. These modes do not carry OAM. The other two modes are degenerate, with modal shapes $\mathbf{e}_1 = (0, -1, 0, 1)$ and $\mathbf{e}_2 = (0, -1, 1, 0)$. A linear superposition of these two eigenmodes with amplitudes b_1 and b_2 :

$$b_1 = \exp(\mp i 2\pi / 3), \quad b_2 = \exp(\pm i 2\pi / 3) \quad (\text{S2})$$

yields two eigenmodes of OAM order $\ell = \pm 1$:

$$b_1 \mathbf{e}_1 + b_2 \mathbf{e}_2 = (0, 1, e^{\pm i 2\pi / 3}, e^{\pm i 4\pi / 3}). \quad (\text{S3})$$

In the twisted PCF these modes become non-degenerate, i.e., the fiber is OAM-state-preserving.