We propose and analyze a new superconvergent local discontinuous Galerkin (LDG) method for the spatial discretization of the second-order wave equation on Cartesian grids. We prove the $L^2$ stability of the scheme and optimal $L^2$ error estimates for the semi-discrete formulation. In particular, we identify special numerical fluxes for which the $L^2$-norm of the solution and its gradient are of order $p+1$, when tensor product polynomials of degree at most $p$ are used. We further show that the LDG solution is $O(h^{p+2})$ superconvergent at Radau points obtained as a tensor product of the roots of $(p+1)$-degree right Radau polynomial. Furthermore, numerical computations show that the first component of the solution’s gradient is $O(h^{p+2})$ superconvergent at tensor product of the roots of left Radau polynomial in $x$ and right Radau polynomial in $y$ while the second component is $O(h^{p+2})$ superconvergent at the tensor product of the roots of the right Radau polynomial in $x$ and left Radau polynomial in $y$. We use the superconvergence results to construct asymptotically correct a posteriori LDG error estimates. Finally, we present several numerical examples to validate the theoretical results. (Received January 06, 2014)