

A wide, horizontal photograph of a large, modern building with a glass facade, reflecting the sky and surrounding trees. The building is surrounded by lush greenery and trees, with a large, dark, leafy tree in the foreground on the right. The sky is a clear, pale blue.

# Second harmonic generation in two-dimensional materials

Journal	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000	1999	1998	1997	1996	1995	1994	1993	1992	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975	1974	1973	1972	1971	1970	1969	1968	1967	1966	1965	1964	1963	1962	1961	1960	1959	1958	1957	1956	1955	1954	1953	1952	1951	1950	1949	1948	1947	1946	1945	1944	1943	1942	1941	1940	1939	1938	1937	1936	1935	1934	1933	1932	1931	1930	1929	1928	1927	1926	1925	1924	1923	1922	1921	1920	1919	1918	1917	1916	1915	1914	1913	1912	1911	1910	1909	1908	1907	1906	1905	1904	1903	1902	1901	1900	1899	1898	1897	1896	1895	1894	1893	1892	1891	1890	1889	1888	1887	1886	1885	1884	1883	1882	1881	1880	1879	1878	1877	1876	1875	1874	1873	1872	1871	1870	1869	1868	1867	1866	1865	1864	1863	1862	1861	1860	1859	1858	1857	1856	1855	1854	1853	1852	1851	1850	1849	1848	1847	1846	1845	1844	1843	1842	1841	1840	1839	1838	1837	1836	1835	1834	1833	1832	1831	1830	1829	1828	1827	1826	1825	1824	1823	1822	1821	1820	1819	1818	1817	1816	1815	1814	1813	1812	1811	1810	1809	1808	1807	1806	1805	1804	1803	1802	1801	1800	1799	1798	1797	1796	1795	1794	1793	1792	1791	1790	1789	1788	1787	1786	1785	1784	1783	1782	1781	1780	1779	1778	1777	1776	1775	1774	1773	1772	1771	1770	1769	1768	1767	1766	1765	1764	1763	1762	1761	1760	1759	1758	1757	1756	1755	1754	1753	1752	1751	1750	1749	1748	1747	1746	1745	1744	1743	1742	1741	1740	1739	1738	1737	1736	1735	1734	1733	1732	1731	1730	1729	1728	1727	1726	1725	1724	1723	1722	1721	1720	1719	1718	1717	1716	1715	1714	1713	1712	1711	1710	1709	1708	1707	1706	1705	1704	1703	1702	1701	1700	1699	1698	1697	1696	1695	1694	1693	1692	1691	1690	1689	1688	1687	1686	1685	1684	1683	1682	1681	1680	1679	1678	1677	1676	1675	1674	1673	1672	1671	1670	1669	1668	1667	1666	1665	1664	1663	1662	1661	1660	1659	1658	1657	1656	1655	1654	1653	1652	1651	1650	1649	1648	1647	1646	1645	1644	1643	1642	1641	1640	1639	1638	1637	1636	1635	1634	1633	1632	1631	1630	1629	1628	1627	1626	1625	1624	1623	1622	1621	1620	1619	1618	1617	1616	1615	1614	1613	1612	1611	1610	1609	1608</
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Two-dimensional (2D) materials, such as graphene, TMDs and gallium mono-chalcogenides, showing great potentials to complement silicon electronics and optoelectronics, have been widely reported for promising optoelectronic devices including photodetectors, modulator, and light emitters. In virtue of shapeable electronic structures, 2D materials also occupy various distinct second harmonic generation (SHG) characteristics, including extraordinarily high efficiency (three orders of magnitude higher than other common nonlinear crystals), layer-dependence, and electrical tunability. If the extraordinary SHGs were exploited further, 2D materials' optoelectronic applications might be greatly extended into nonlinear regimes for coherent light source generations, image processings, ultrafast laser engineering, etc. In this talk, we would report our two recent work about SHG in 2D materials.

First, we report the layer-dependent second harmonic generation (SHG) in atomic layered ReS<sub>2</sub>. Different from most of the atomically thin transition metal dichalcogenides, e.g., MoS<sub>2</sub> and WS<sub>2</sub>, monolayer ReS<sub>2</sub> has no SHG, and strong SHG can only be obtained from a even-layered ReS<sub>2</sub> flake. From a bilayer ReS<sub>2</sub> flake, we obtain an effective second order nonlinear susceptibilities of 900 pm/V, which is the highest value reported in 2D materials at the telecom-band.

Second, We demonstrate the first achievement of continuous-wave (CW) pumped second harmonic generation (SHG) in few- and mono-layer gallium selenide (GaSe) flakes, which are coated on silicon photonic crystal (PC) cavities. Because of ultrahigh second order nonlinearity of the two-dimensional (2D) GaSe and localized resonant mode in the PC cavity, VKJ pump power is greatly reduced to microwatts. In a nine-layer GaSe coated PC cavity, while the optical power inside the GaSe flake is only 1.5% of that in the silicon PC slab, the SHG in GaSe is more than 650 times stronger than the third harmonic generation in silicon slab, indicating 2D J dVh great potentials to strengthen nonlinear processes in silicon photonics. Our study opens up a new view to expand 2D d h ld optoelectronic applications in nonlinear regime and chip-integrated active devices.

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**Photograph by Xiaodong Hu**