# 亮点报道：基于准连续域束缚态的高效硅基红外非线性上转换成像技术

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近年来，随着微纳加工技术的发展，基于超表面的非线性光学调控成为了领域内的研究重点。然而，超表面在非线性频率转换效率方面一直难以满足实用化需求。如何在微纳尺度下进一步增强光与物质相互作用，利用 Q 因子共振提升非线性转换效率，是目前红外成像技术向微型化、高性能迈进的关键科学问题。

南昌大学信息工程学院研究团队提出并实验验证了一种基于准连续域束缚态的硅基非线性超表面，实现了高效的红外上转换成像。在 SOI 平台上设计了由硅纳米圆盘与椭圆盘构成的二聚体单元，通过精确控制椭圆盘在 x 轴上的面内对称性破缺，将 BIC 转化为具有有限寿命的 quasi-BIC 共振。这种单向扰动策略有效抑制了辐射损耗，实验测得 Q 因子最高可达 4000。得益于强局域场增强效应，在 1533 nm 飞秒脉冲泵浦下，超表面产生的 THG 信号强度相比未图案化硅膜提升 650 倍以上，绝对转换效率达 $3\times10^{-5}$，打破了硅基超表面的效率记录。

团队还搭建了非线性上转换成像系统，采用西门子星分辨率靶标测试，上转换后的可见光图像空间分辨率约为 6 μm，对复杂字符图案也展现出高保真度。该成果为开发微型化、高性能、室温工作的红外传感器及全光信息处理器件提供了重要技术支撑。

# Highlights: Ultra-efficient infrared imaging with smart silicon metasurfaces

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Advancing infrared imaging is vital for security, automation, and science, but conventional infrared detectors are limited by costly cooling and inferior performance compared to silicon sensors.However, early upconverters using bulky nonlinear crystals hinder miniaturization. Metasurfaces offer an integrated platform but suffer from low nonlinear conversion efficiency.

The research team of Nanchang University provides a definitive solution using quasi-bound states in the continuum (quasi-BIC). They designed a metasurface with paired silicon nanodisks and controlled asymmetry, transforming a trapped optical mode into a high-quality, leaky resonance with a Q-factor up to 4000. This acts as a nanoscale light trap, drastically enhancing silicon's third-order nonlinearity. Under infrared pump light, the metasurface achieves a third-harmonic generation efficiency of $3\times10^{-5}$, setting a new benchmark for CMOS-compatible silicon metasurfaces.

Beyond efficiency, the platform enables direct upconversion imaging, acting as a parallel array of pixel-level converters. Arbitrary infrared images are faithfully translated into visible images with a resolution of 6 μm at room temperature using a single pump laser. This research establishes a scalable paradigm for deployable, miniaturized infrared imaging and sensing solutions for autonomous systems, industrial monitoring, and consumer electronics.

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