铁电畴壁非线性光学特性研究

Nonlinear optical properties of ferroelectric domain wall

铁电晶体畴壁的研究在过去仅局限于唯象的或第一性原理的理论计算，直到近两年，畴壁上的新颖功能性逐渐显示出巨大潜力。通过对铁电晶体畴壁激发切伦科夫倍频的详细分析，我们发现铁电晶体畴壁上存在巨大提升的非线性光学响应。利用这一性质，我们提出了利用畴壁切伦科夫倍频信号重建畴壁形态的成像方法；设计了高效的飞秒光全带宽倍频方案；以及利用畴壁序列实现完全位相匹配倍频。

Study of ferroelectric domain walls (DWs) was limited to phenomenological or first principle calculations in the past , however, in recent times there has been increasing focus on novel functionality at DWs. Through detailed analysis of Cherenkov second harmonic generation (CSHG), we found that there is a huge increase of nonlinear optical response. Based on this character, we proposed a new method of reconstructing the DW image by collecting the signals of CSHG; designed high efficiency full bandwidth second harmonic generation (SHG) of femtosecond pulses; and achieved complete-phase-matching SHG by ferroelectric domain wall series.

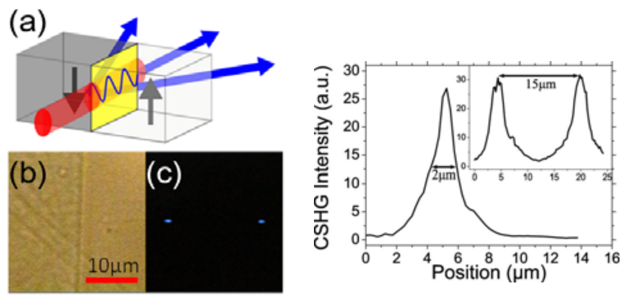

Figure 1 | Cherenkov second harmonic generation (CSHG) at domain walls
图1 | 畴壁上的切伦科夫二次谐波

畴壁上区域出现了比体介质中强得多的切伦科夫二次谐波，出射角度θ=**arcos(v_2/v_1)**，**v_2, v_1**分别为基频光和倍频光的相速度。

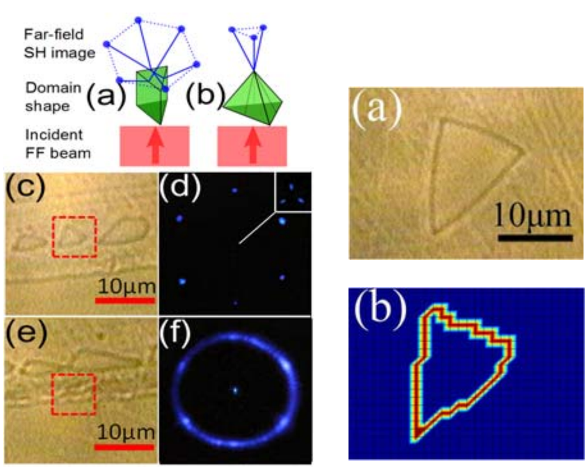

Figure 2 | Reconstructing the DW image by collecting the signals of CSHG
图2 | 利用畴壁上的切伦科夫二次谐波进行畴壁检测

我们在实验上观测到不同的畴结构可以产生与之对应的切伦科夫二次谐波图样，以此建立的畴壁检测和畴壁图样重建技术具有高达**10mrad**的角分辨率。

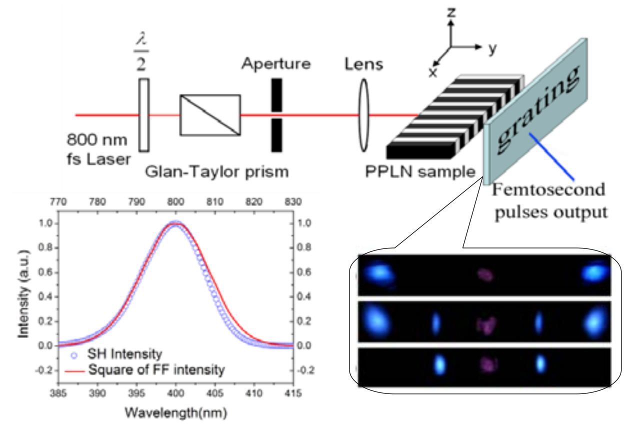

Figure 3 | High efficiency full bandwidth SHG of femtosecond pulses by periodically poled lithium niobate (PPLN)
图3 | 利用周期性极化铌酸锂实现超宽带的飞秒脉冲全带宽倍频

由于切伦科夫二次谐波出射角度与波长相关，理论上可以对全带宽实现倍频，光谱分析结果表明，这一方案中倍频光对基频光实现了完美复制。

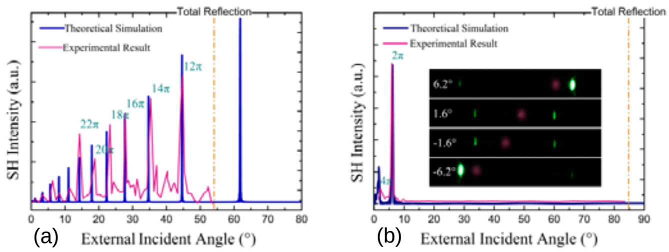

Figure 4 | Complete-phase-matching CSHG by ferroelectric domain wall series in 30μm PPLN sample (a) eee type CSHG (b) ooe type CSHG
图4 | 30μm PPLN样品中畴壁序列切伦科夫二次谐波完全位相匹配

某些特定的入射角度上，不同畴壁产生的切伦科夫二次谐波相干相涨，从而实现了完全为相匹配。其中，最高归一化转换效率出现在**ooe**型匹配，相位差为**2**π时的入射角度上，每个经过一个周期**0.5%/W**，这个效率比目前报道的**QPM**最高的每周期**0.37%/W**还要高。

先进光子学材料和物理实验室
Laboratory of Advanced Photonic Materials and Physics