English

山东大学 Shandong University

Research Progress on Metal ions doped Lithium Tantalate Crystals and Their Applications in Green Laser

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Shandong University

Outline

Background

Main Content

I. Synthesis of uniformly MgO doped SLT crystal powder by liquid method

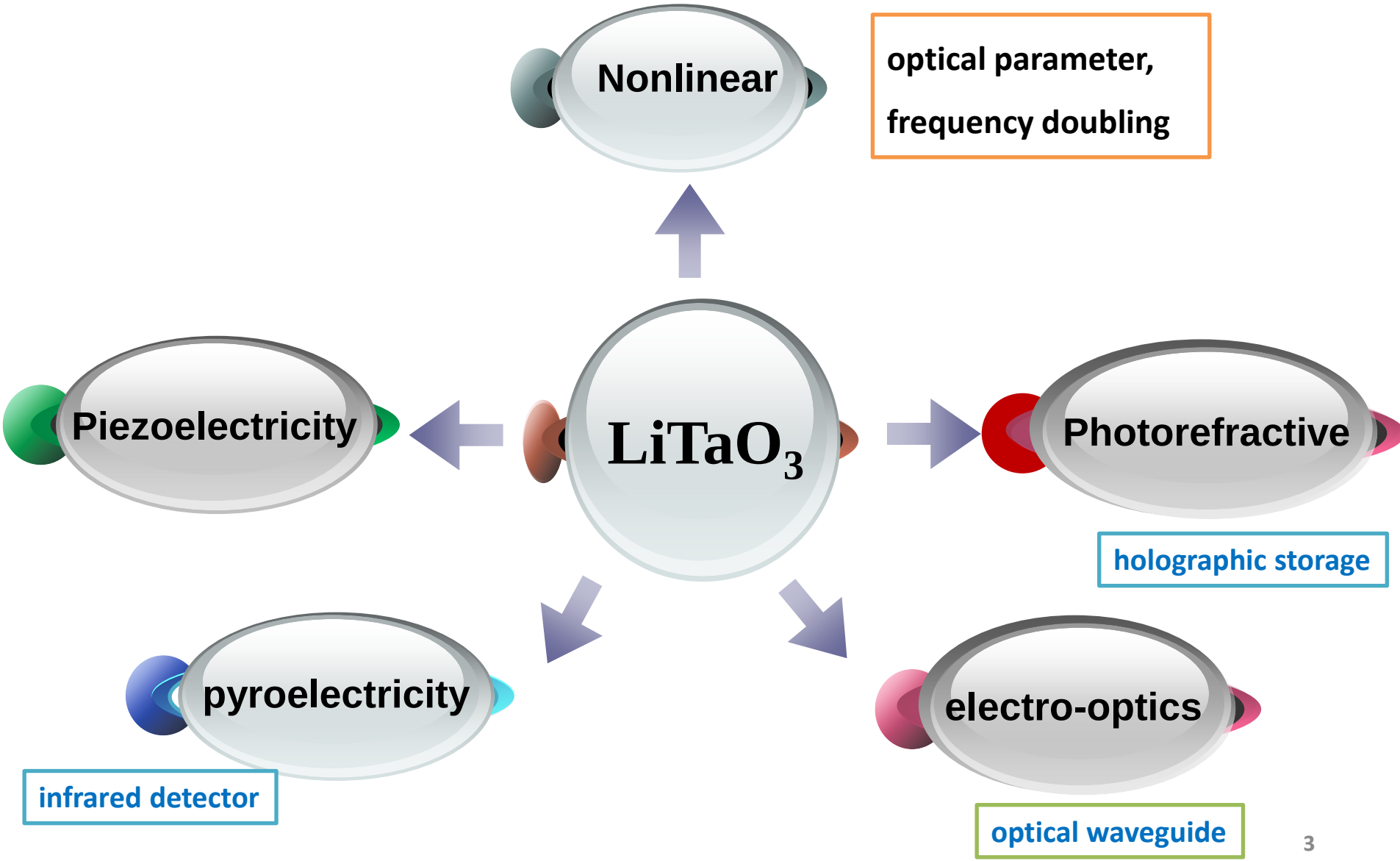
II. Crystal growth and characterization of SLT and MgOSLT crystals

III. Crystal growth and characterization of Nd, Mg co-doped LT crystals

IV. Applications in Laser of Nd, Mg co-doped LT crystals

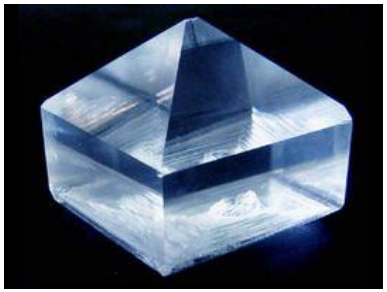
Summary

Background

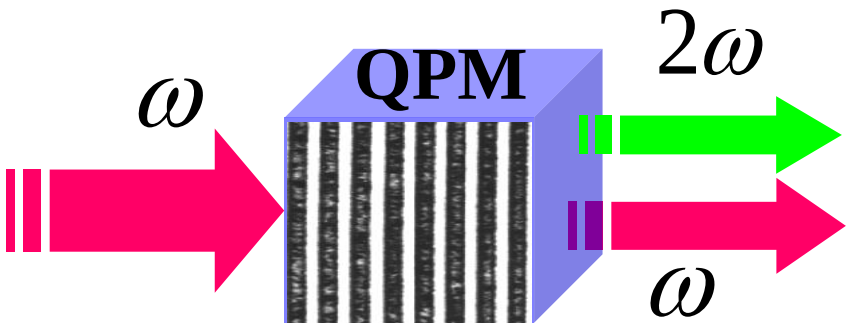

Nonlinear
optical parameter,
frequency doubling
Piezoelectricity
$LiTaO_3$
Photorefractive
holographic storage
pyroelectricity
infrared detector
electro-optics
optical waveguide

Background

Select of nonlinear crystals :

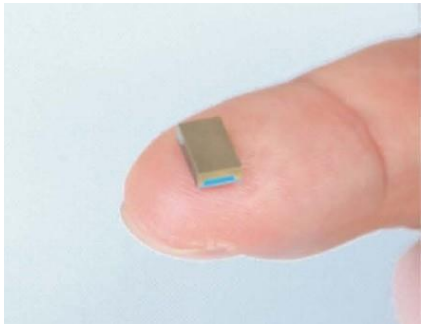






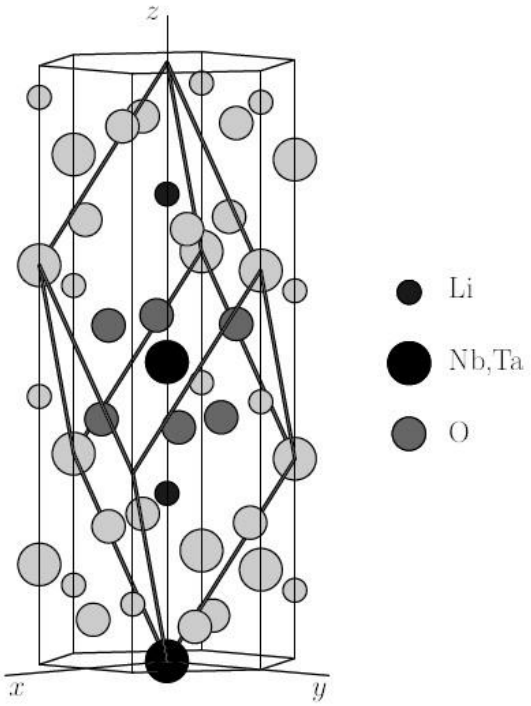




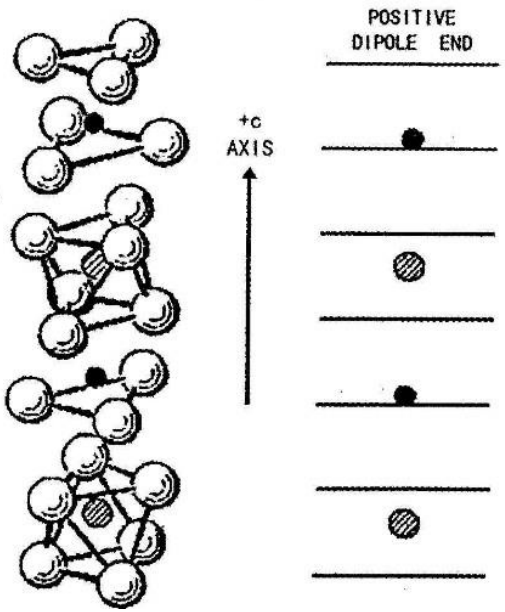


PPMgO:LN

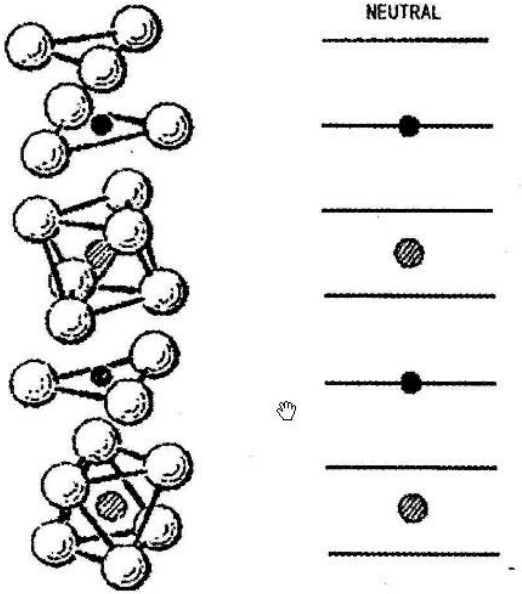
Background



Unit cell of $LiTa(Nb)O_3$



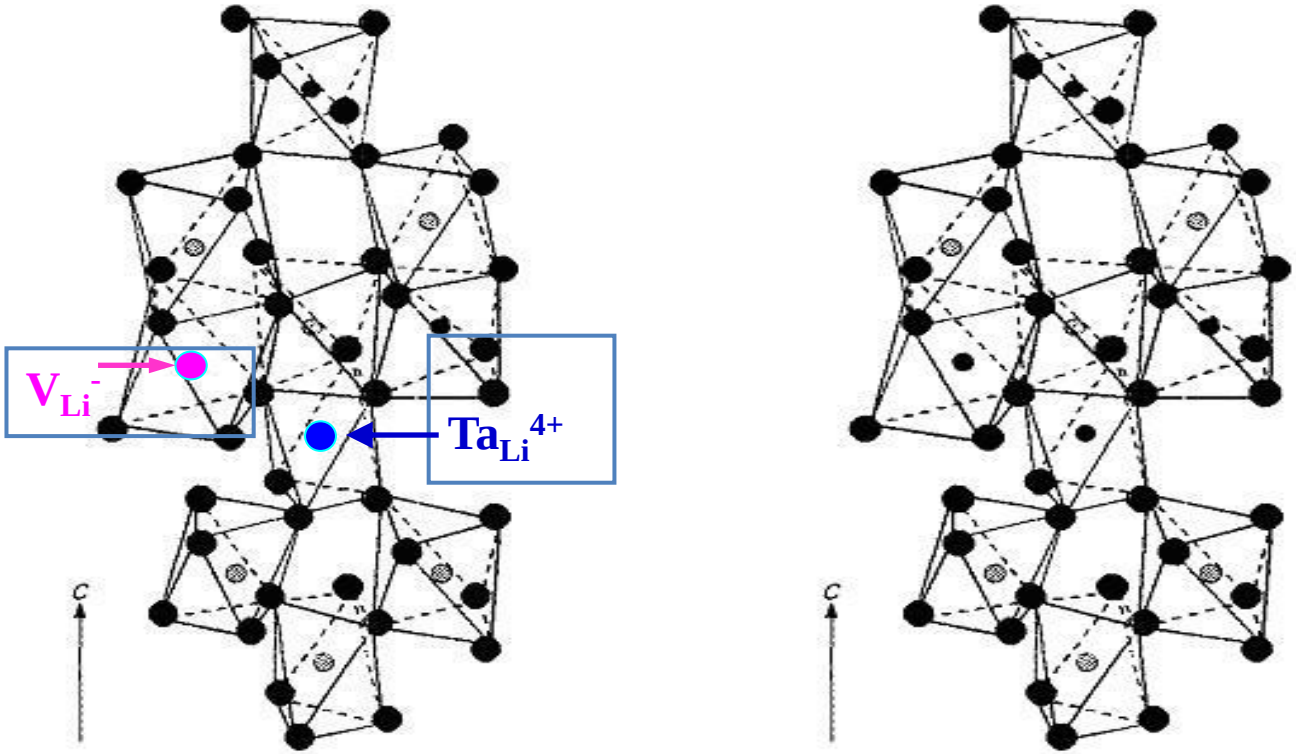
Ferroelectric phase



Paraelectric phase

Two kinds of unit cell of LT and ferroelectric/paraelectric transform

Background



Non-stoichiometric

Stoichiometric

Progress in physical properties

Background

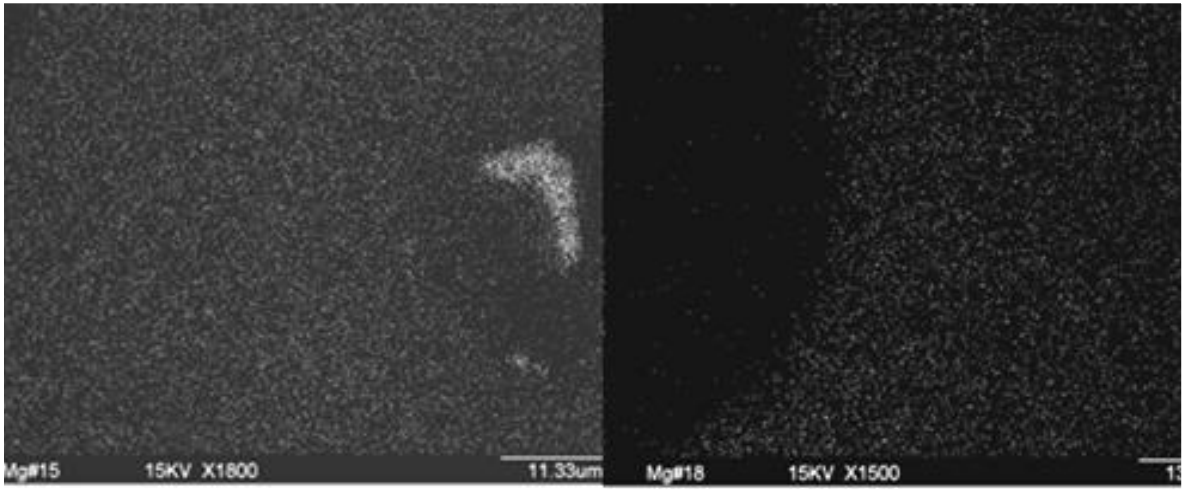
SLN



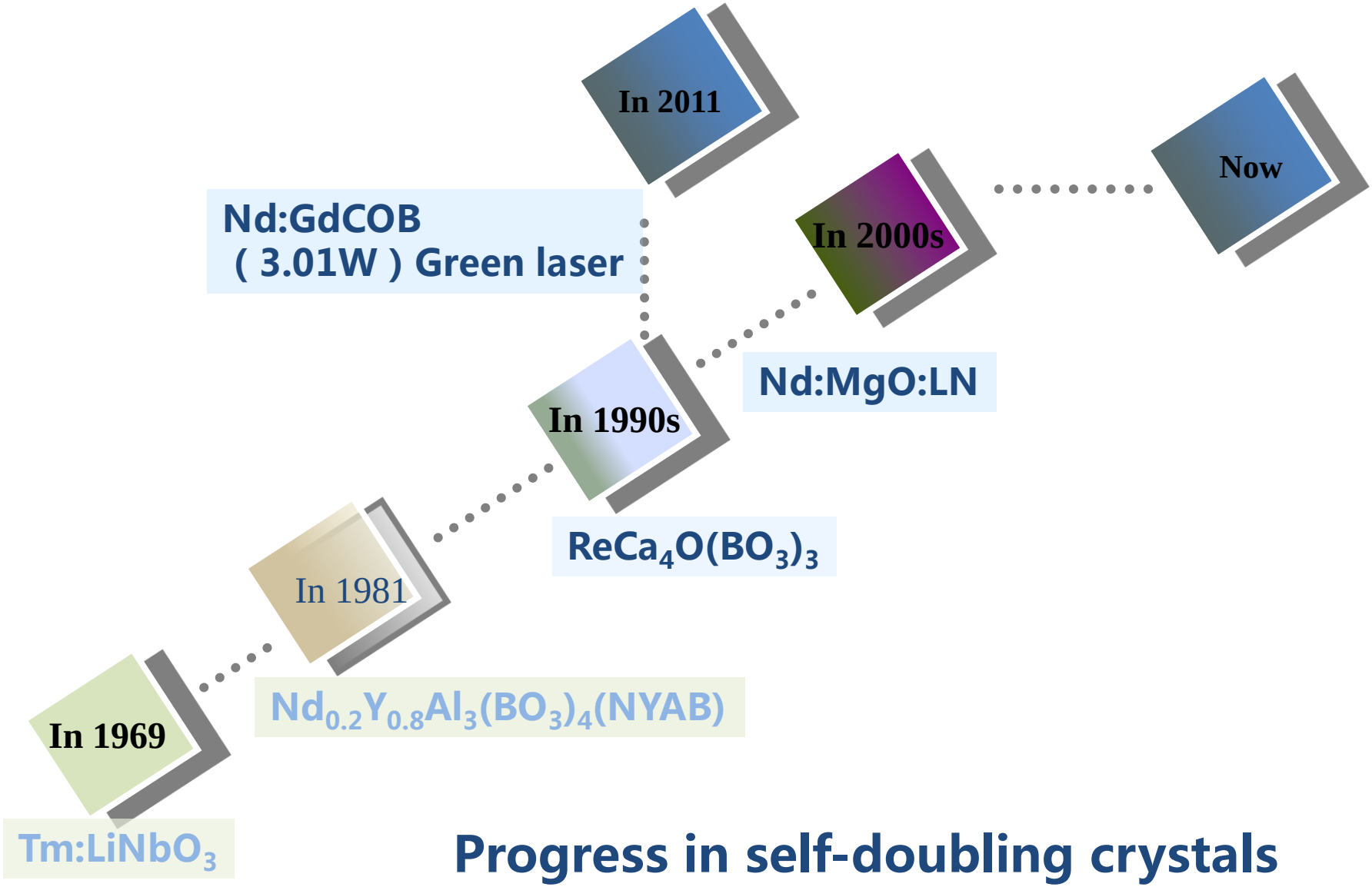
SLT



MgO:SLN



Background



Progress in self-doubling crystals

Main Content

Synthesis of uniformly MgO doped SLT crystal powder by liquid method

Applications in Laser of Nd, Mg co-doped LT crystals

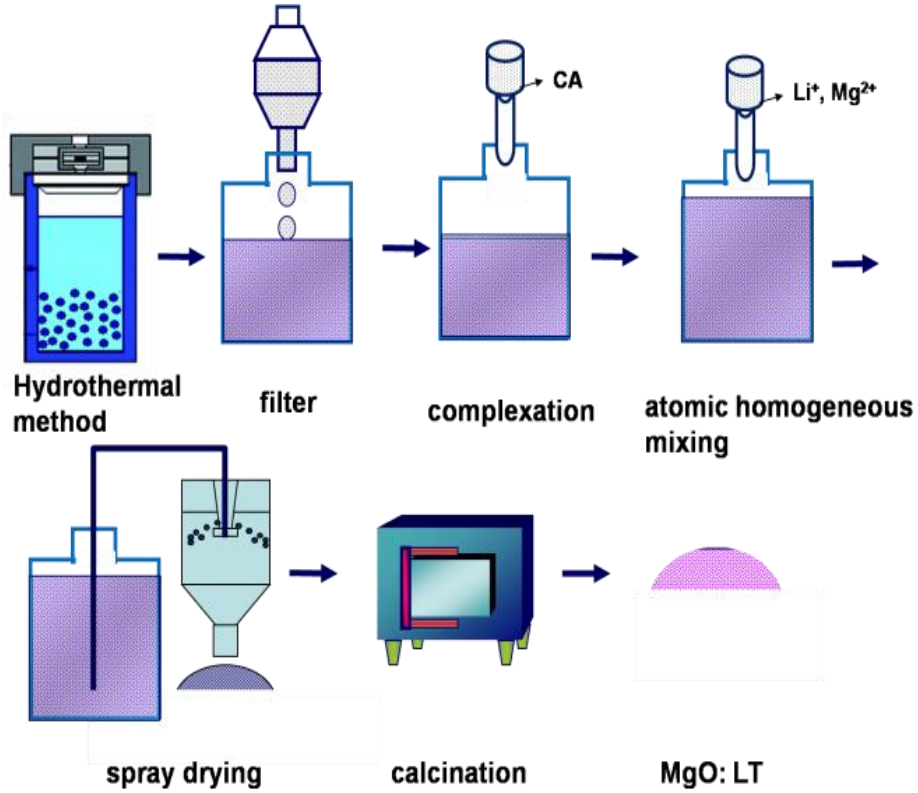
Crystal growth and characterization of SLT and MgOSLT crystals

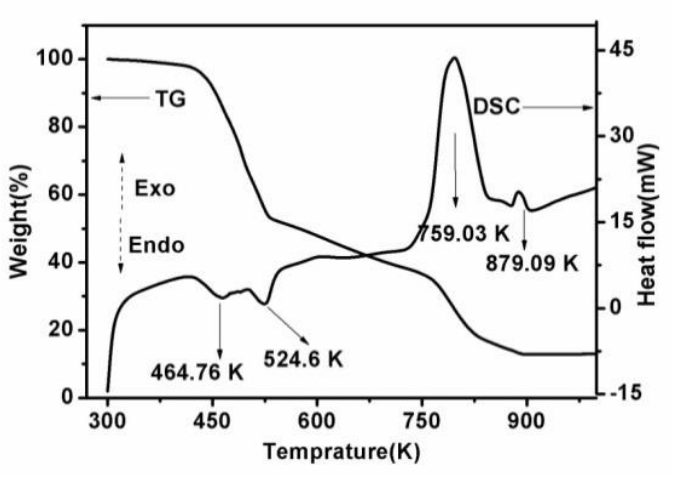
Crystal growth and characterization of Nd, Mg co-doped LT crystals

MgO:SLT Crystal powder by liquid method

Solid reaction $Li_2CO_3+Ta_2O_5 \rightarrow LiTaO_3+CO_2$

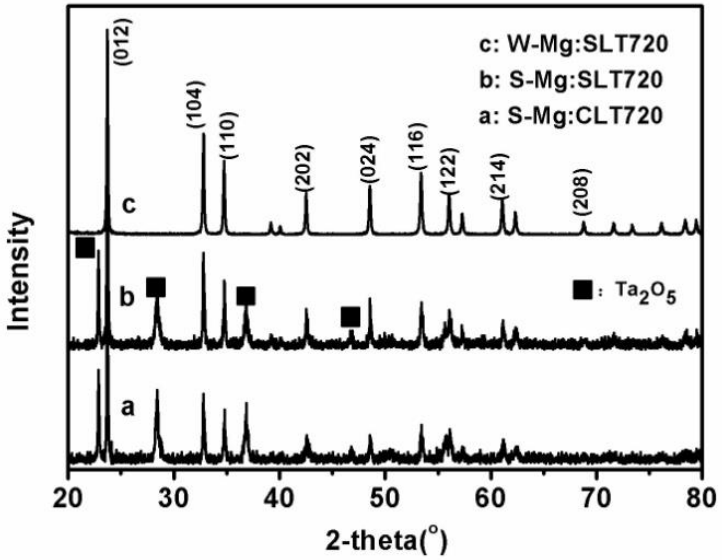
Liqiud method



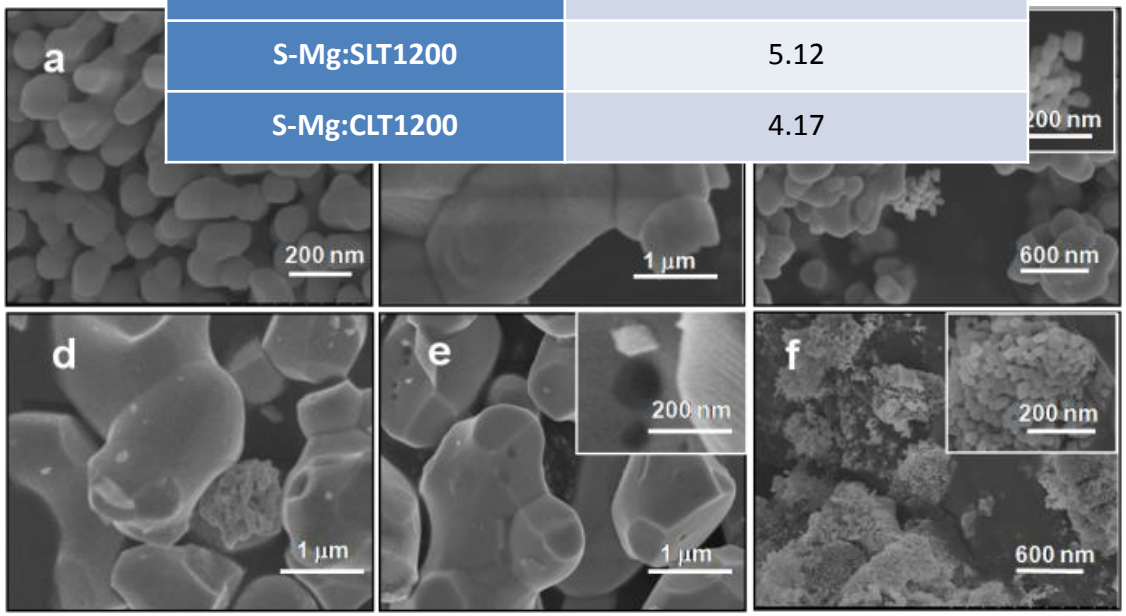


W-Mg:SLT720: calcined at 720 °C ;
W-Mg:SLT1200: calcined at 1200 °C

MgO:SLT Crystal powder by liquid method

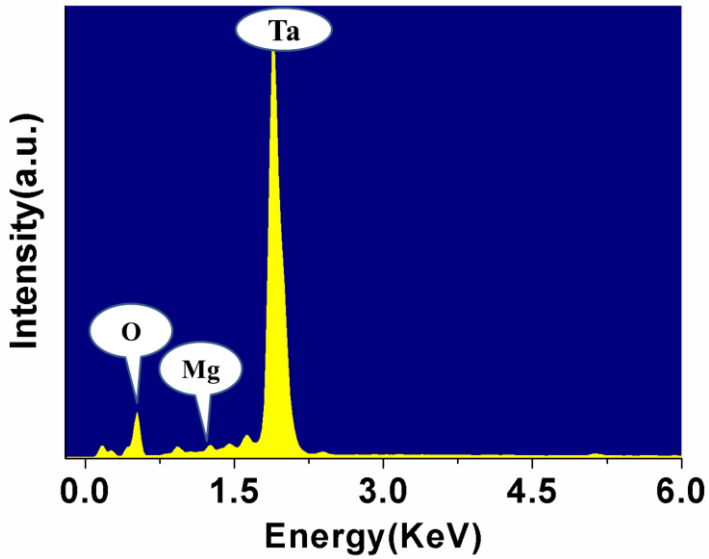


Sample	R（wt. %）
W-Mg:SLT720	0.81
S-Mg:SLT720	40.2
S-Mg:CLT720	39.3
S-Mg:SLT1200	5.12
S-Mg:CLT1200	4.17



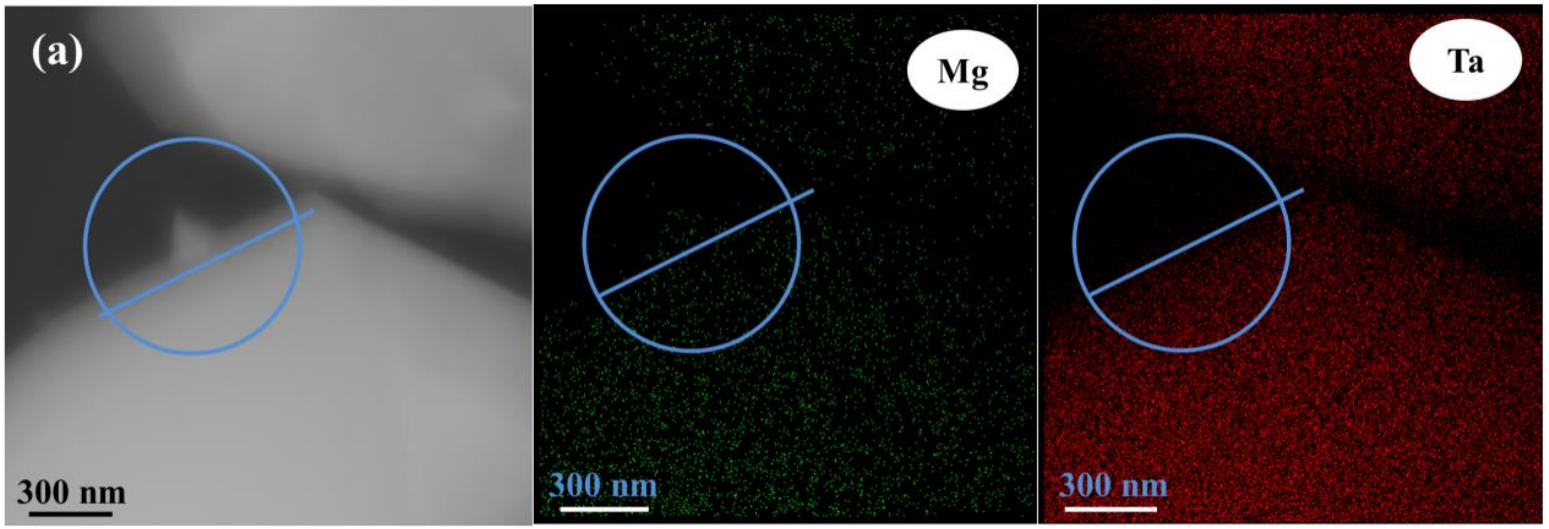
SEM (a) W-Mg:SLT720, (b) W-Mg:SLT1200, (c) S-Mg:SLT720, (d) S-Mg:SLT1200, (e) S-Mg:SLT1200 corrosion in HCl, (f) MgO720.

MgO:SLT Crystal powder by liquid method

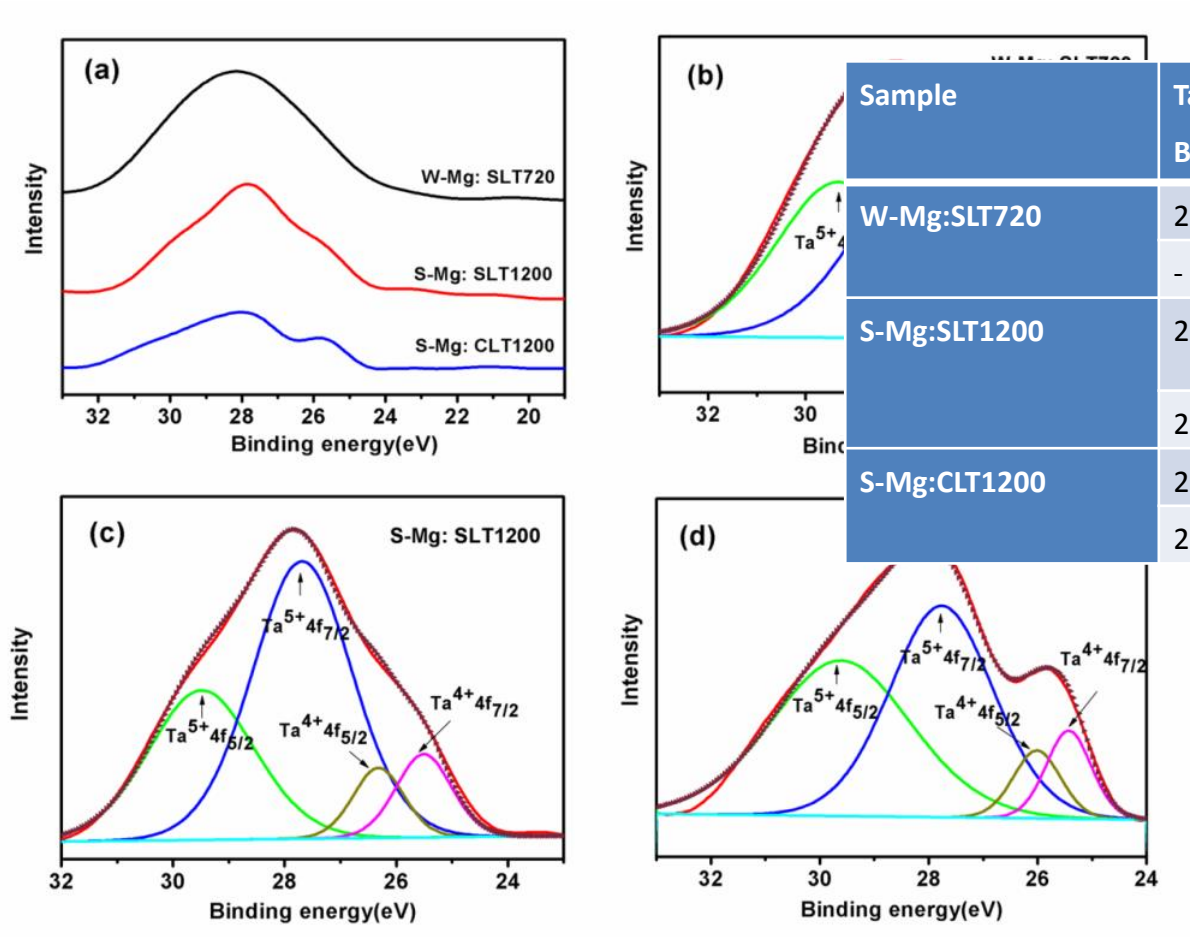


MgO phase in solid method

TEM(a) and mapping of Mg、Ta



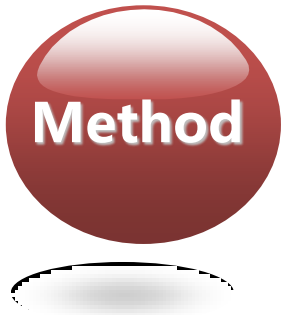
MgO:SLT Crystal powder by liquid method



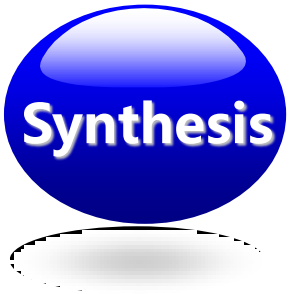
Sample	$Ta4f_{7/2}$ BE (eV)	Chemical state	At. %
W-Mg:SLT720	27.6	Ta^{5+}	100
	-		0
S-Mg:SLT1200	27.7	Ta^{5+}	95.1
	25.5	Ta^{4+}_{Li}	4.9
S-Mg:CLT1200	27.7	Ta^{5+}	90.2
	25.6	Ta^{4+}_{Li}	9.8

Crystal growth of SLT&MgO:SLT



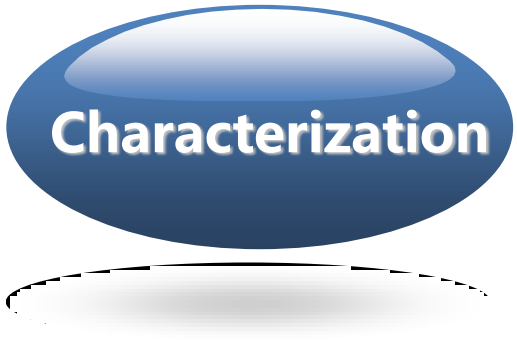


Cz method



Li-rich crystal powder——solid reaction with 58.6 mol%Li

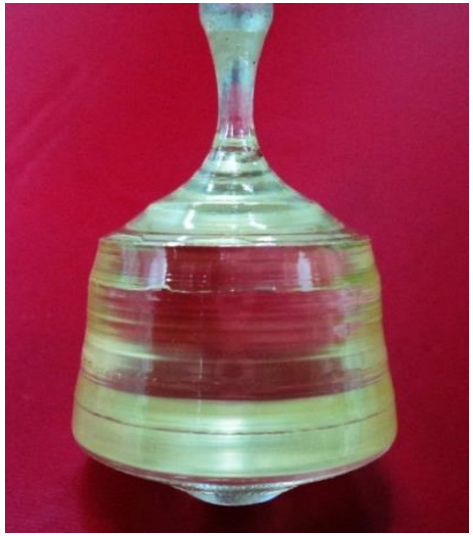
MgO doped Li-rich crystal powder——liquid method 58.6 mol%Li, 1 mol%Mg



Optical, thermal

Crystal growth of SLT&MgO:SLT

SLT

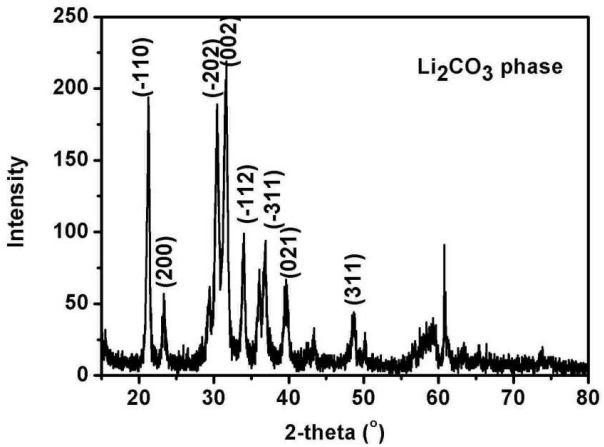




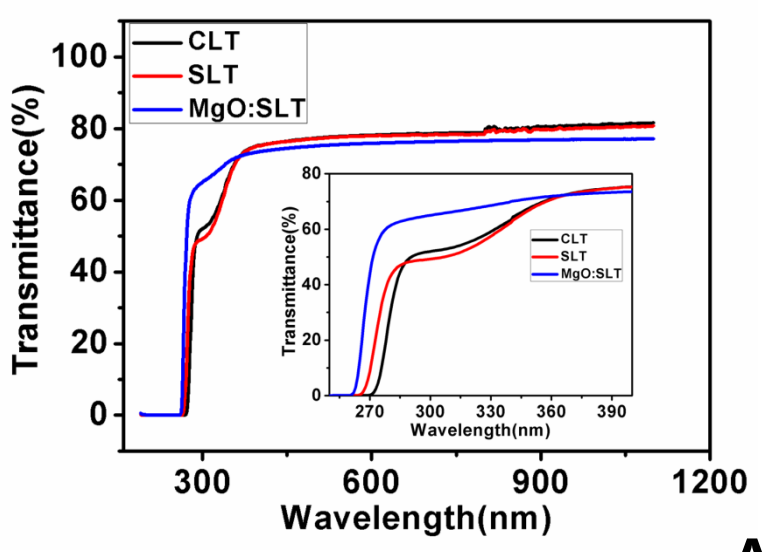


MgO:SLT





Optical properties



Transmittance of CLT, SLT&MgO:SLT crystals

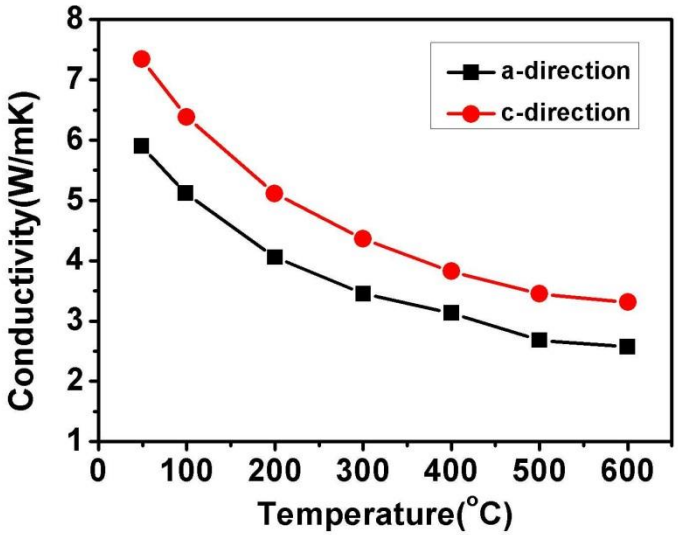
MgO:SLT own the widest optical range !

Absorption edge of CLT , SLT&MgO:SLT

Crystal(melting component)	Absorption edge/nm	*Reference edge/nm
CLT (Li 48.75 mol%)	273	275
SLT (Li 58.6 mol%)	266	260
MgO:SLT (Mg 1 mol%)	262	266

Thermal properties

Crystal(melting component)	Curie point/°C	*Reference Curie point/ °C
CLT (Li 48.75 mol%)	604.5	601±1 (Li 48.5 mol%)
SLT (Li 58.6 mol%)	690.9	685±1 (Li 59 mol%)
MgO:SLT (Mg 1 mol%)	699.5	695±1 (Mg 1 mol%)



	MgO:SLT	MgO:CLT*
k_a W/(m·K)	5.901	3.83
k_c W/(m·K)	7.343	4.54

Conductivity of MgO doped LT crystals

Crystal growth of Nd:MgO:CLT

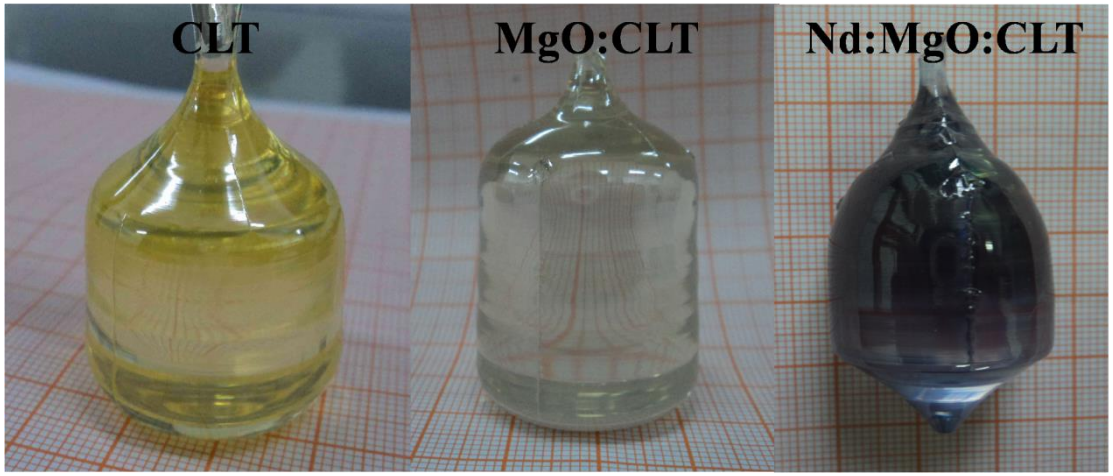


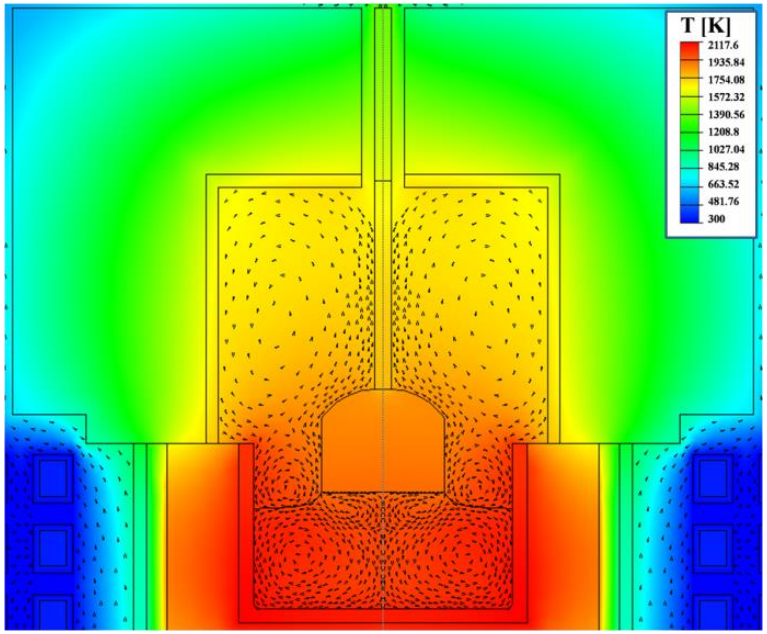
Method — Cz method

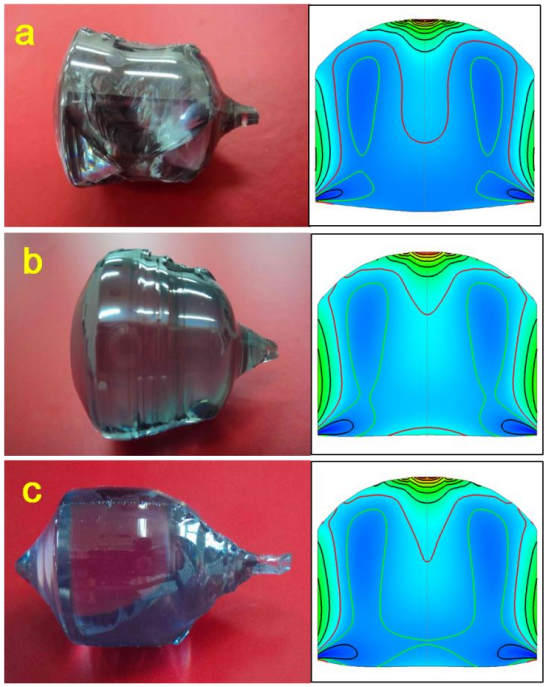
Synthesis — Liquid method
Nd:MgO:CLT 0.5 mol%Nd, 5 mol%Mg
CLT 48.75 mol%Li
MgO:CLT 5 mol%Mg

Characterization — Elements segregation, optical

Crystal growth







Von Mises stress, Pa

5.4E7
4.8E7
4.3E7
3.8E7
3.2E7
2.7E7
2.2E7
1.6E7
1.1E7
5.7E6
3.7E5

CGSim

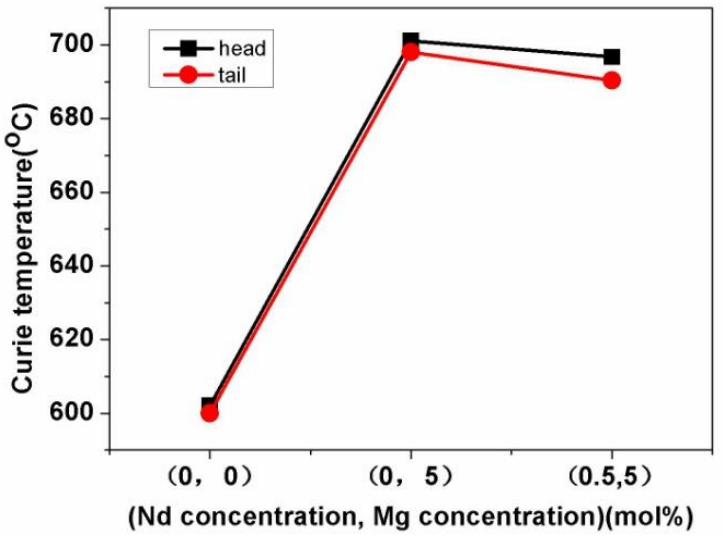
Segregation coefficient of Nd

Doping concentration : Nd 0.5 mol%, Mg 5 mol%

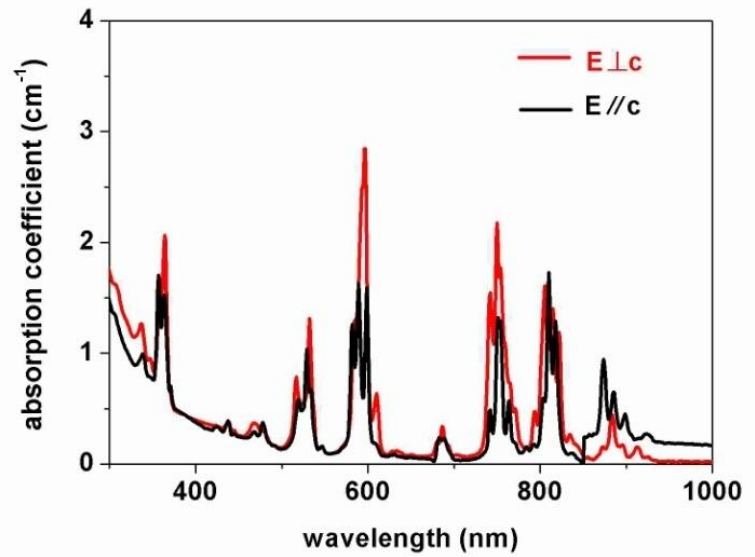
	Standard (wt.%)	Crystal (wt.%)	k_{eff} (c_s/c_l)
Nd	0.303	0.194	0.64
Mg	0.511	0.597	1.17
Ta	76.02	76.08	1.00

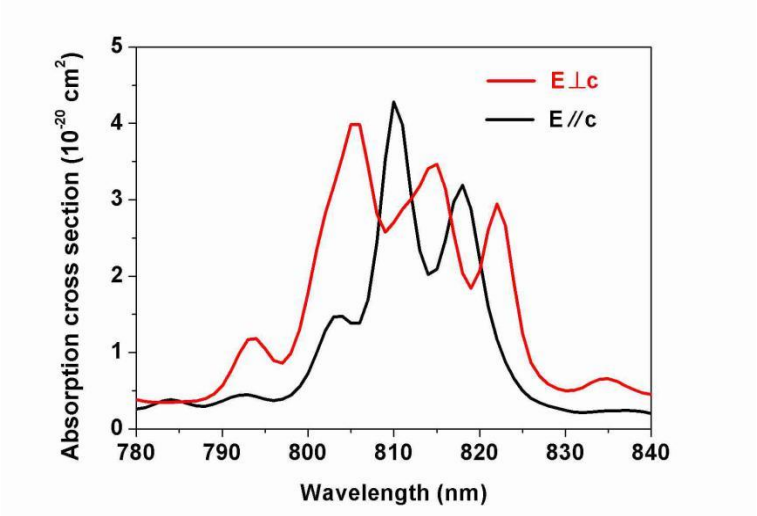
Segregation coefficient of Nd gets smaller as increasing of Mg concentration !

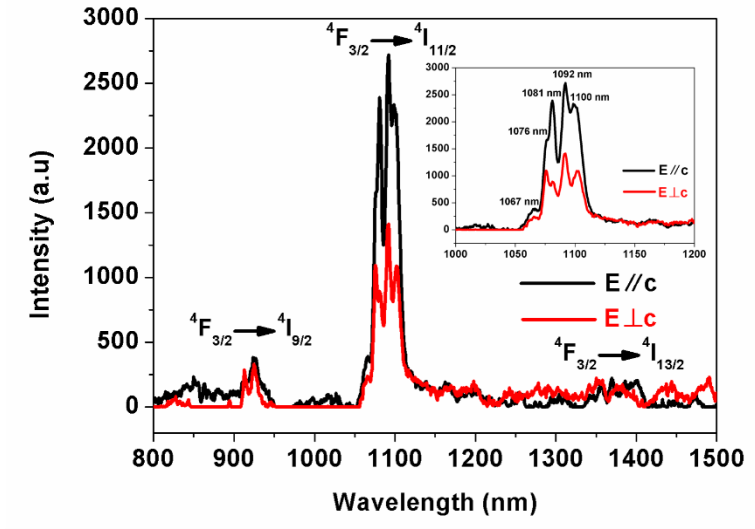
Curie temperature image shows that doping with Nd makes the Curie temperature lower



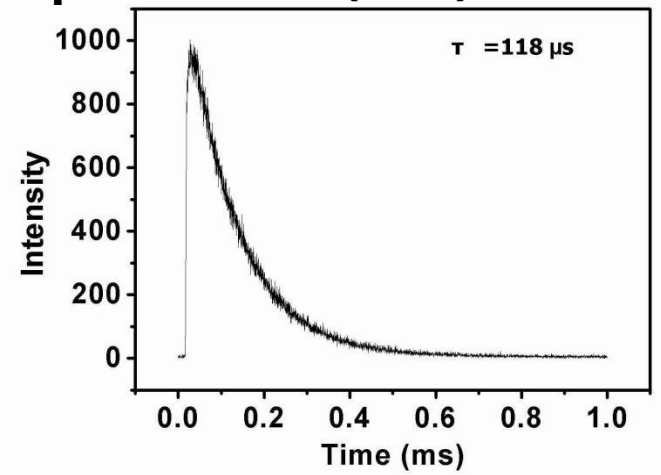
Optical properties



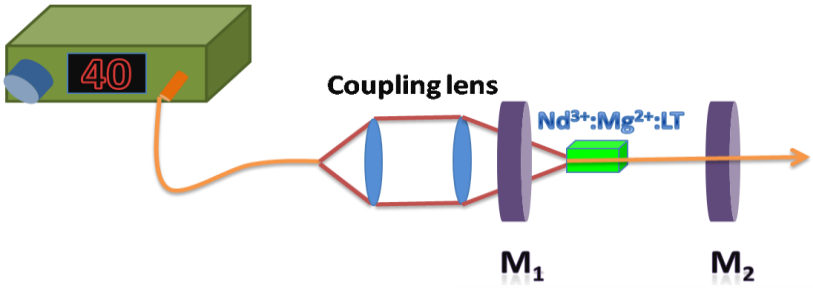




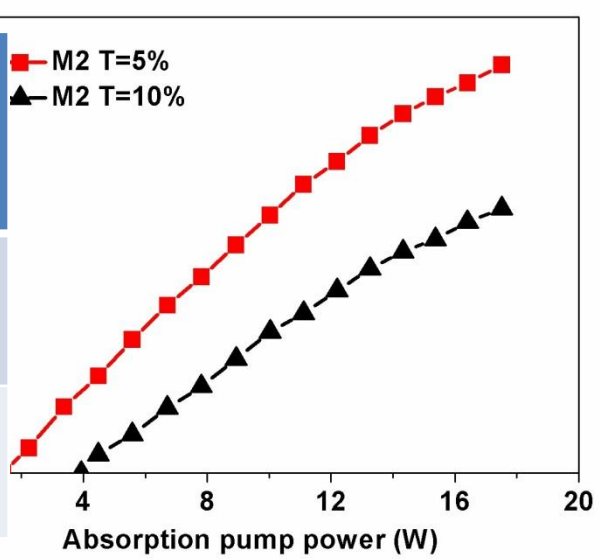
σ-polarization(E⊥*c*)&π-polarization(E//*c*)



Continuous laser performance

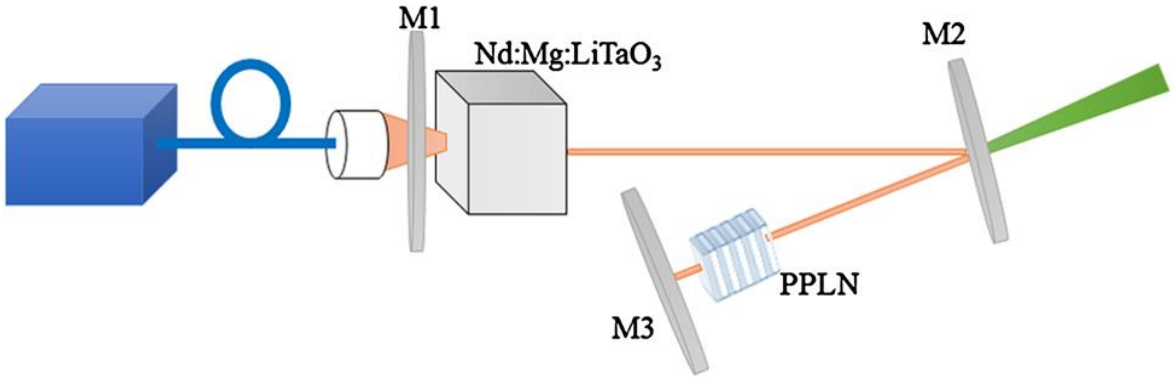


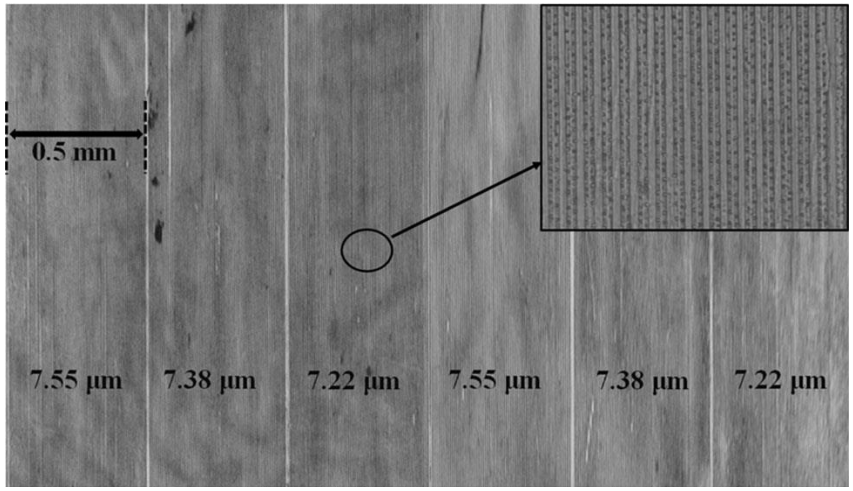
	Pumping threshold(W)	Max output (W)	Light conversion efficiency	slope efficiency
5%@1064 nm	1.40	3.58	22.78%	26.06%
10%@1064 nm	3.96	2.32	13.54%	17.38%



c-cut Nd:MgO:CLT sample

Green laser Generation



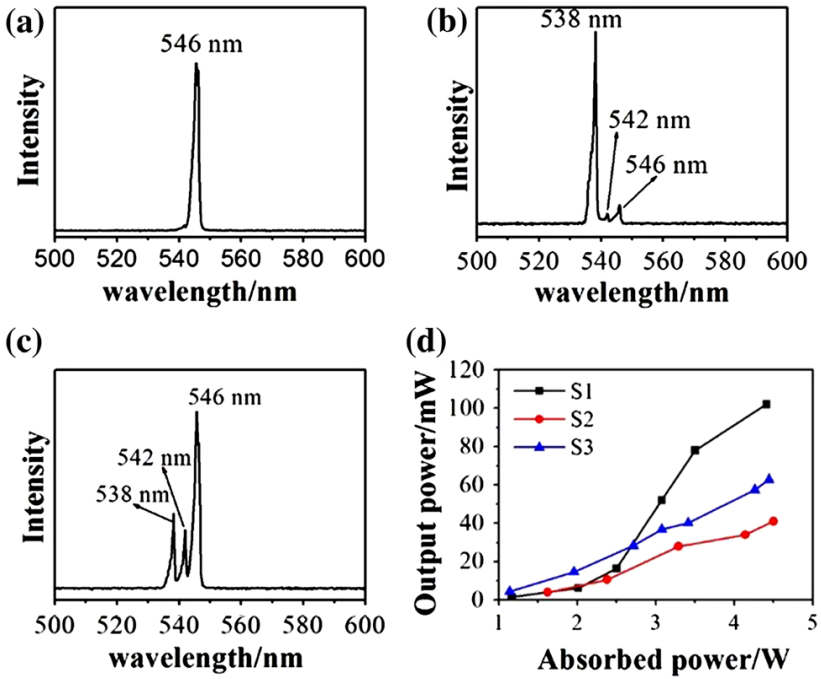


Periodic structure of S3. The inset shows the +Z image of S3

Table 1 Mg:PPLN crystals used in this experiment

Serial number	Period (μm)	Total crystal length (mm)	Predicted wavelength (nm)
S1	7.55	2	546
S2	7.22	2	538
S3	7.55&7.38&7.22 (0.5 mm each)	3	546&542&538

Green laser Generation



Spectrum for: a) S1; b) S2; c) S3. d) The output power of the three samples

Table 1 Mg:PPLN crystals used in this experiment

Serial number	Period (μm)	Total crystal length (mm)	Predicted wavelength (nm)
S1	7.55	2	546
S2	7.22	2	538
S3	7.55&7.38&7.22 (0.5 mm each)	3	546&542&538

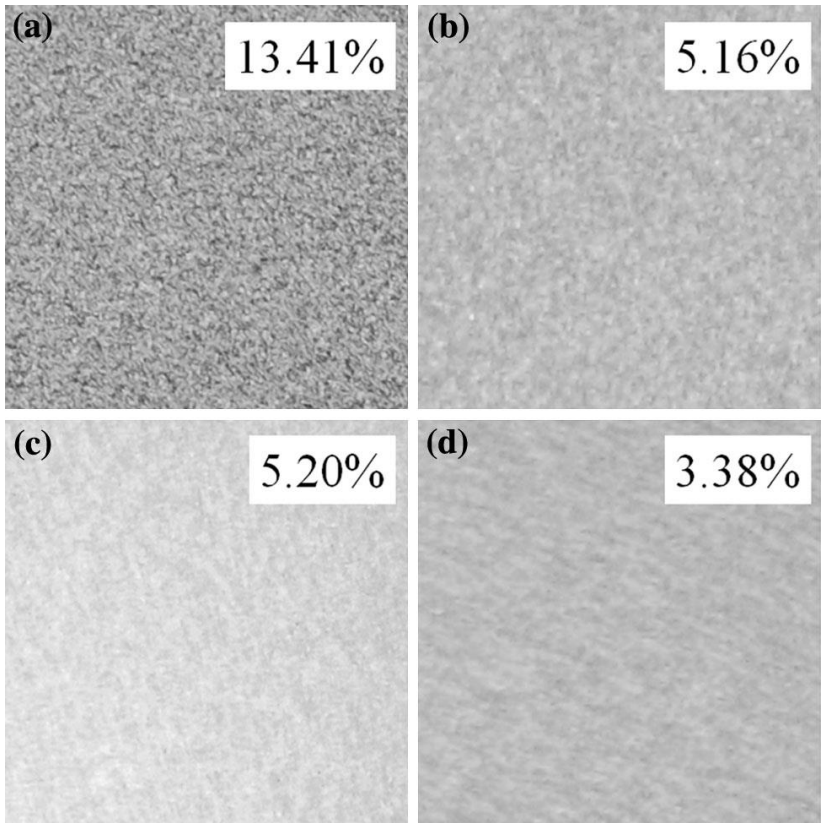
A total power of 62.8 mW for the three-wavelength green laser was obtained from absorbing 4.4 W of power from the pumping laser at 808 nm, corresponding to a conversion efficiency of 1.4 %.

Laser speckle measurements

$$C_0 = \frac{\sigma_I}{\langle I \rangle} = \frac{\sqrt{\langle I^2 \rangle - \langle I \rangle^2}}{\langle I \rangle}$$

$$= \sqrt{\frac{1}{\sqrt{1 + 2\pi^2 \left(\frac{\delta v}{\bar{v}}\right)^2 \left(\frac{\sigma_h}{\bar{\lambda}}\right)^2 (\cos\theta_0 + \cos\theta_i)^2}}}$$

Speckle patterns of: a） the 532-nm laser generated using frequency doubling of Nd:YVO_4; b） the 546-nm laser; c） the 538-nm laser; d） the three-wavelength laser



Summary

1. First time to synthesize the MgOSLT by liquid method and grow the crystal.

2. Growth of Nd:MgO:CLT crystals and obtained 3.58 W continuous laser.

3. A total power of 62.8 mW for the three-wavelength green laser was obtained .

Thank You!