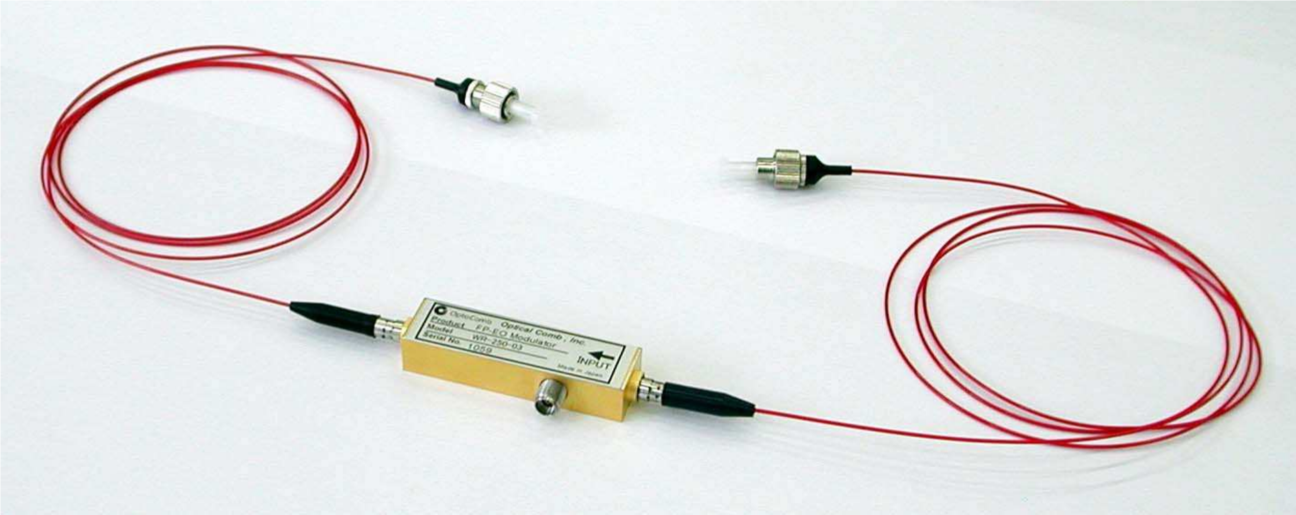
# Effect of corona poling parameters on polymer film poling eficiency

Eduards Titavs, Edgars Nitišs, Mārtiņš Rutkis

*Institute of Solid State Physics, University of Latvia, Riga*

# Aim and motivation

- Use of nonlinear optical polymer materials in electro-optical devices, such as electro-optical (EO) modulator, to achieve higher modulation speeds
- EO polymer materials have higher nonlinearity, are cheaper and easier to produce



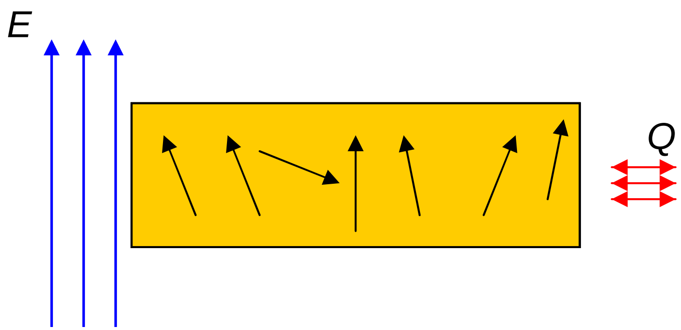
# NLO material comparison

| Parameter | *Inorganic crystal $LiNbO_3$* | *Organic EO material* | *Semiconductor EO device* |
|---|---|---|---|
| EO coefficient $r_{eff}$, [pm/V] | *30* | *>300* | *16* |
| Relative dielectric permittivity $\varepsilon_r$ | *30* | *3-4* | *12* |
| *Working frequency* | *40 Ghz* | *>100 Ghz* | *40 Ghz* |

# Nonlinearity in polymer materials

Poling using external electric field

- Placing a sample in an external electric field
- Adding heat to the sample
- Orientation of chromophores occur
- Cooling the sample
- Turn off the electric field
- After this procedure the sample should have a certain polarization



# Orientation of chromophores

- *Order parameter of chromophores in the polymer sample*

$$\left\langle \cos^3 \vartheta \right\rangle = \frac{\mu E}{5kT}\left[1 - L^2\left(\frac{W_{e.s.}}{kT}\right)\right]$$

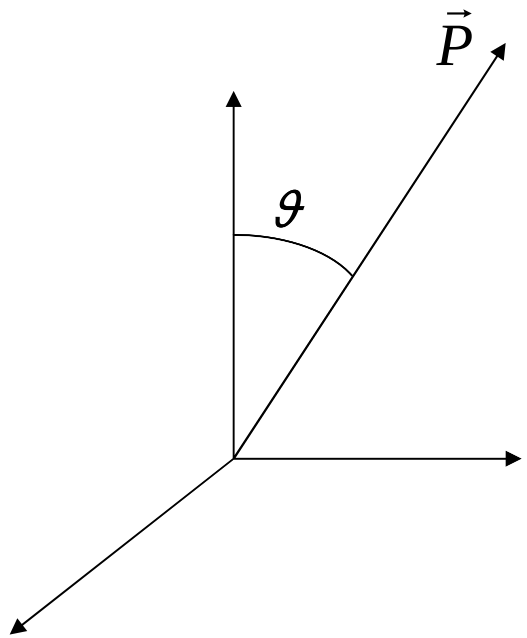
$\vartheta$ – angle between dipole moment and external electric field

$E$ – poling electric field

$\mu$ – dipole moment of chromophore

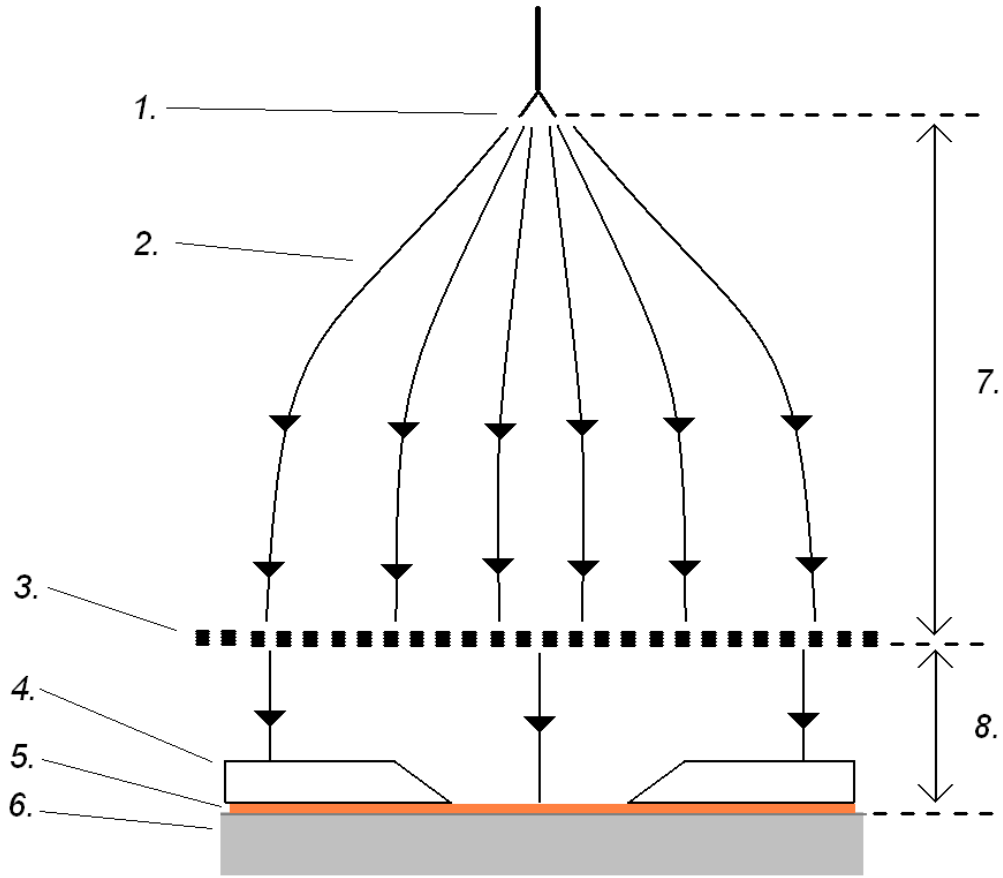
$L$ – Langevin function

$W_{e.s.}$ – Electro-static energy between the chromophores



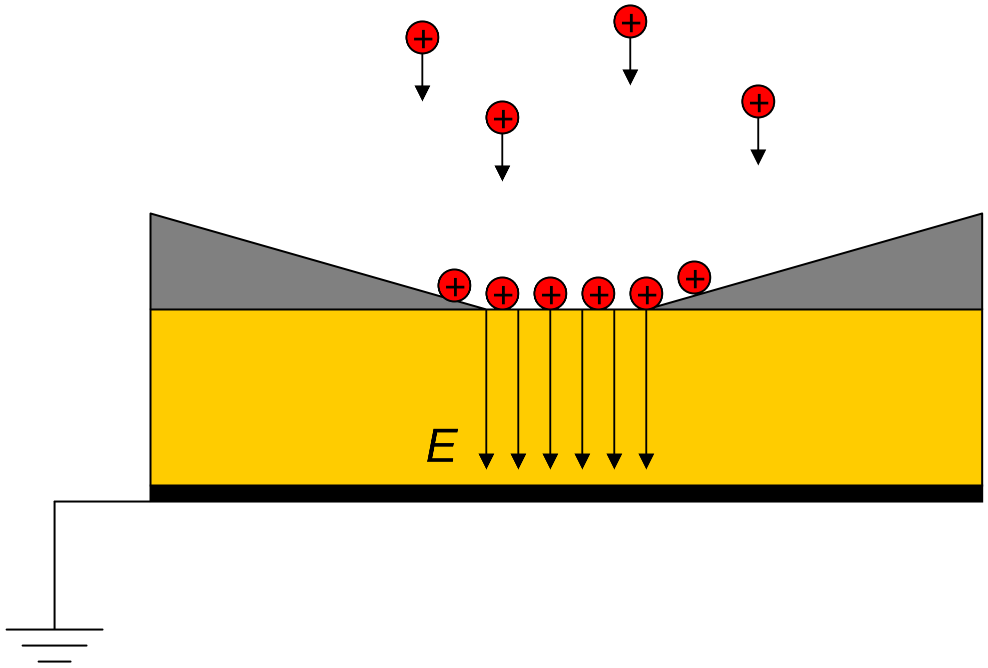
# Corona triode device for poling

1. Corona needles
2. Electric field lines
3. Grid
4. Spacer
5. Sample
6. Glass substrate with ITO coating
7. Voltage between corona needles and grid
8. Voltage between grid and ITO coating



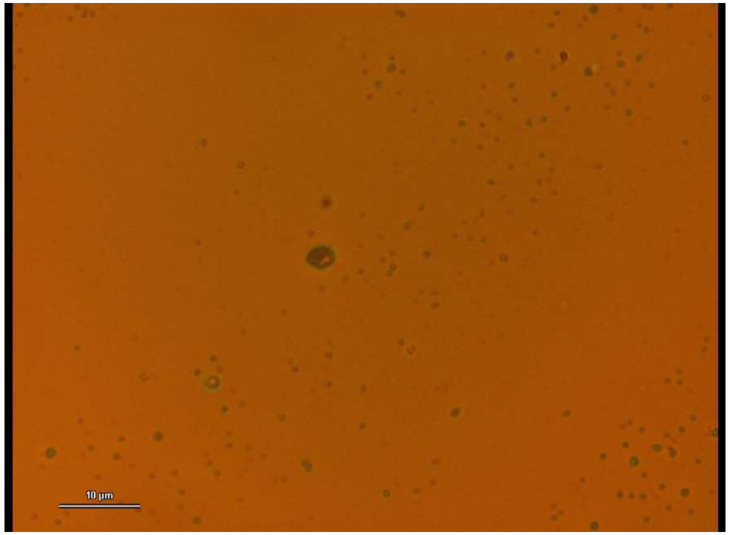
# Spacer betweed the sample and grid

- Allows us to pole only the middle region of the sample – we can then analyse two regions, poled and unpoled

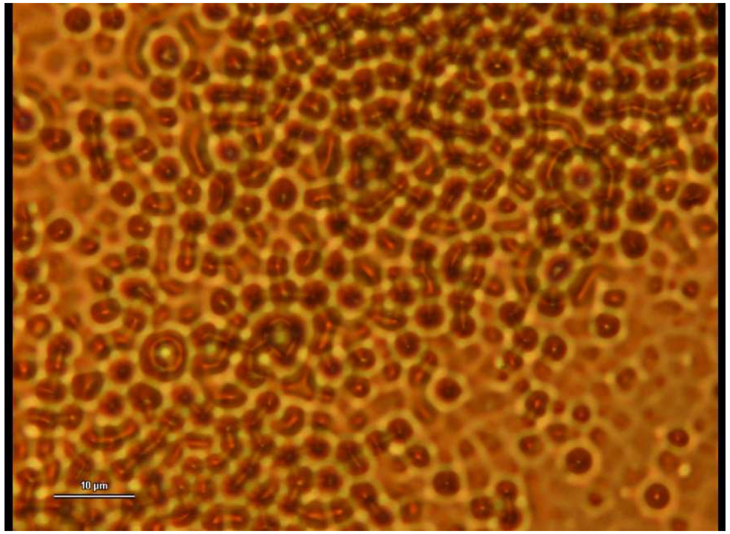


# Problems

- If the temperatureis close to the glass transition temperature of the material and grid potential is high enough, formation of irregularities occur in the poled region of the sample
- These irregularities scatter the light that passes through the sample, as a result the total nonlinearity decreases



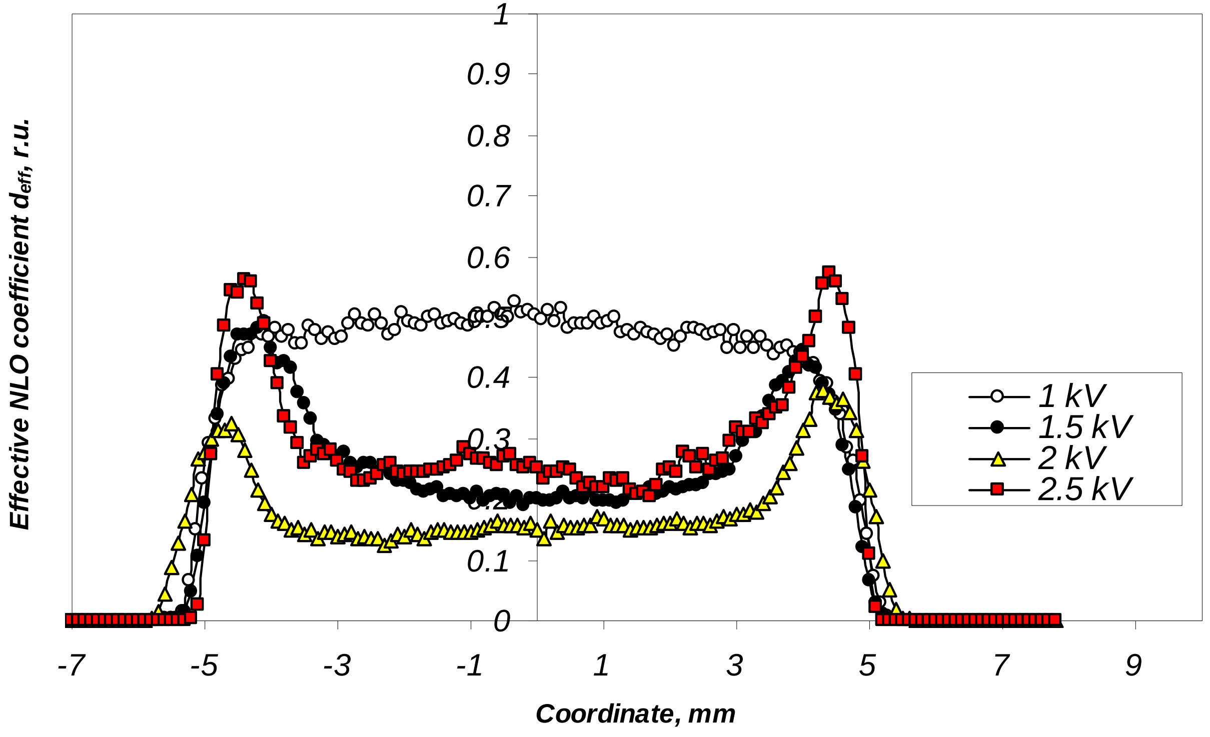

a) Before poling - 100x magnified

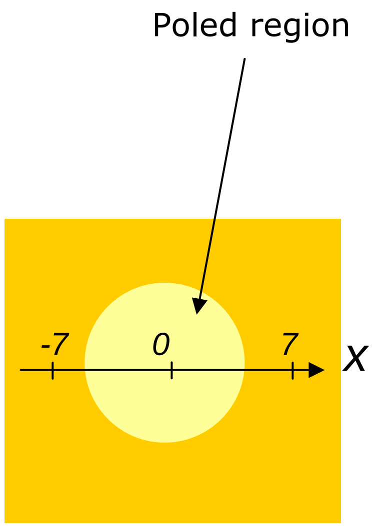



b) After poling - 100x magnified

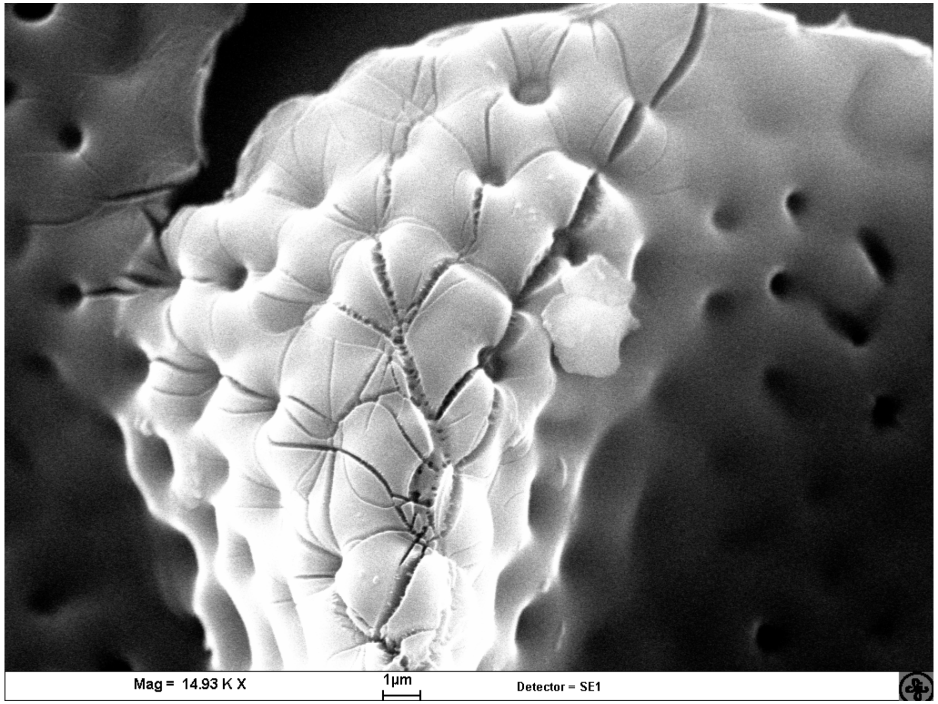
# Second harmonic generation in the sample

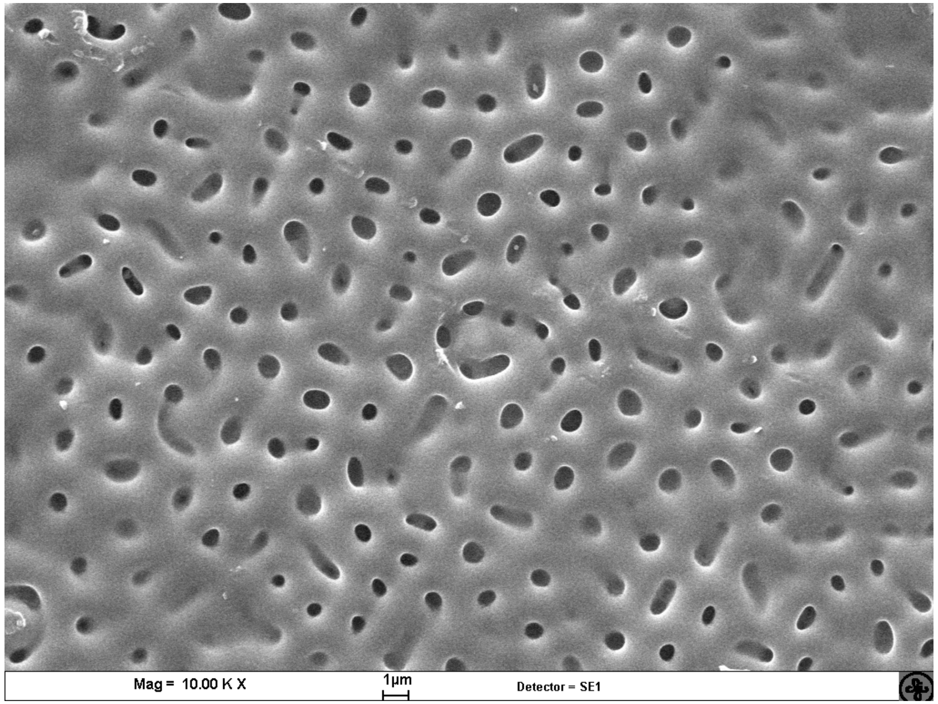
SHG generation => effective NLO coefficient $d_{eff}$



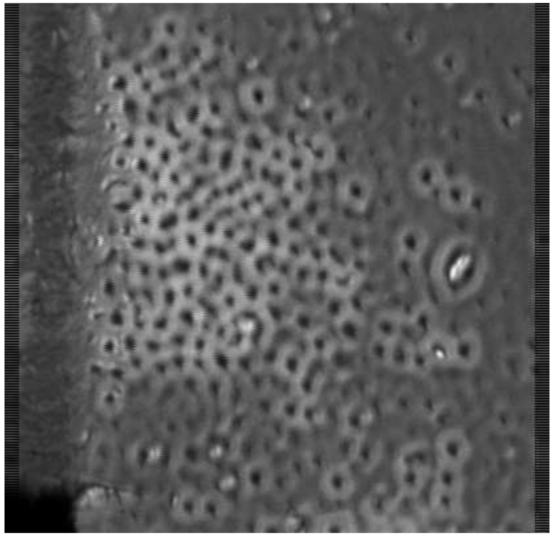



# Electron microscope pictures of a poled polymer sample

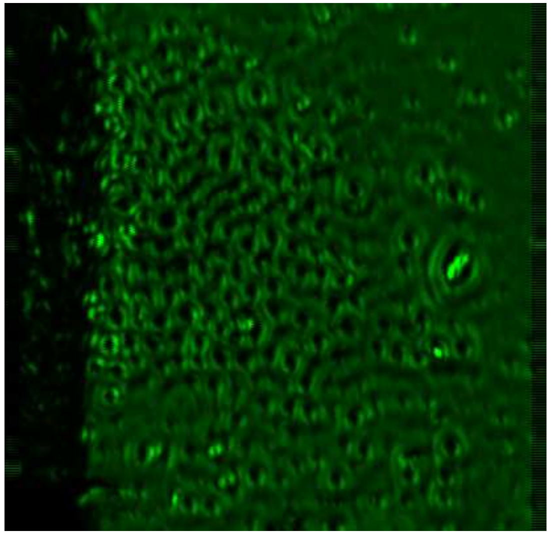


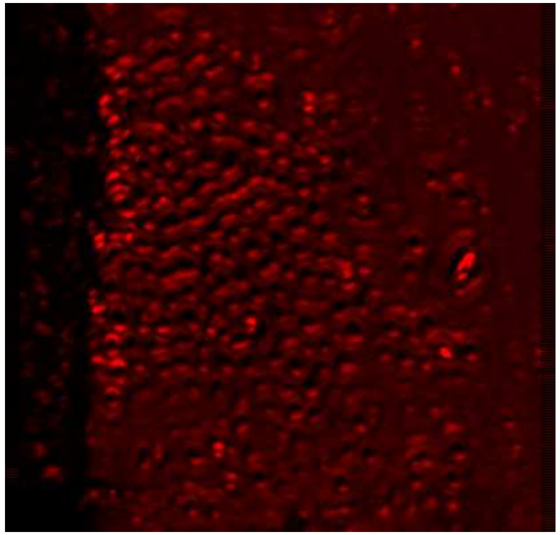
# Second harmonic (SH) microscope pictures



Two-photon luminescence

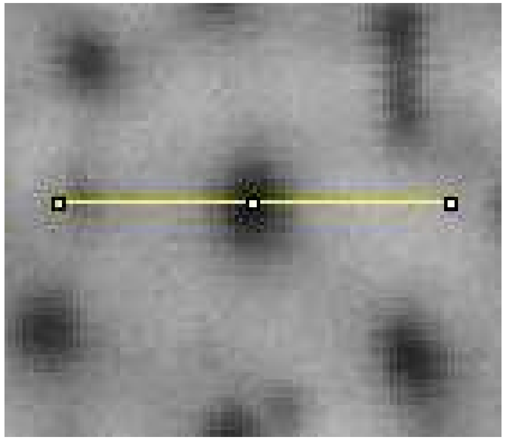


SH intensity distribution (polarization 0º)

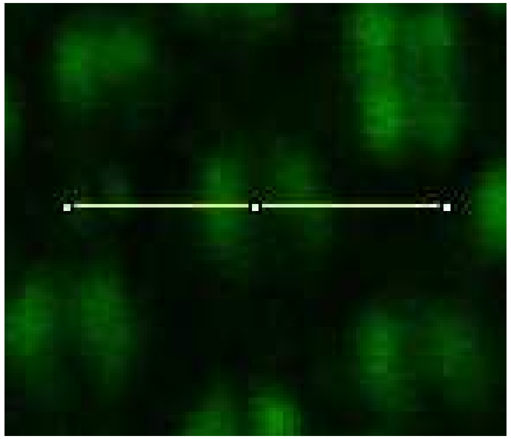


SH intensity distribution (polarization 90º)

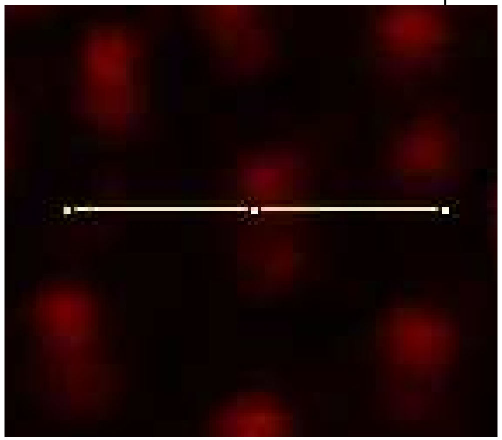
# Second harmonic (SH) microscope pictures



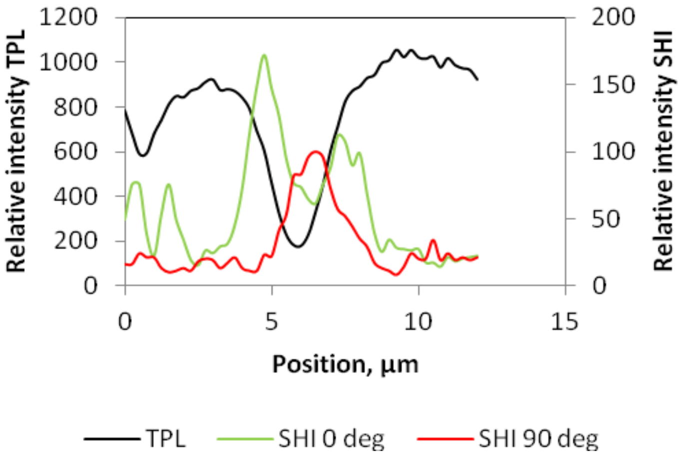
Two-photon luminescence



SH intensity distribution (polarization 0º) ⟷



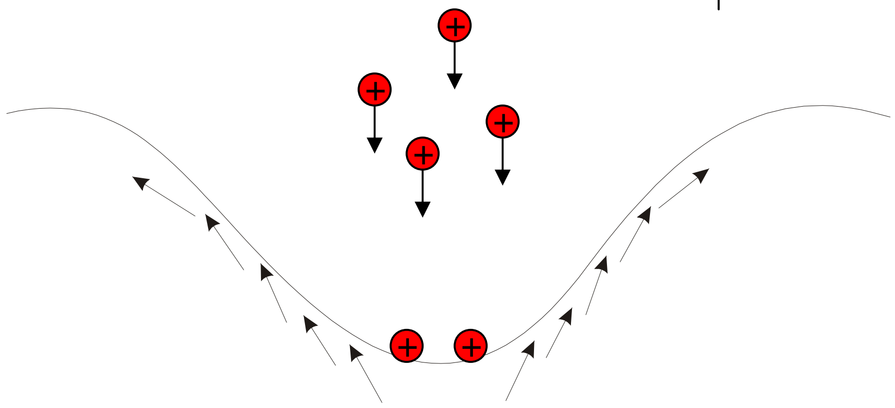
SH intensity distribution (polarization 90º) ↕

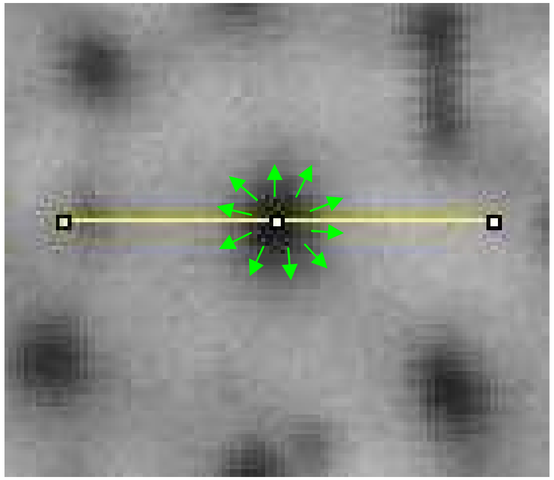



- Highest SH generation intensity is on the slopes of a pore
- SH generates all around the pore

# Dipole orientation in pores

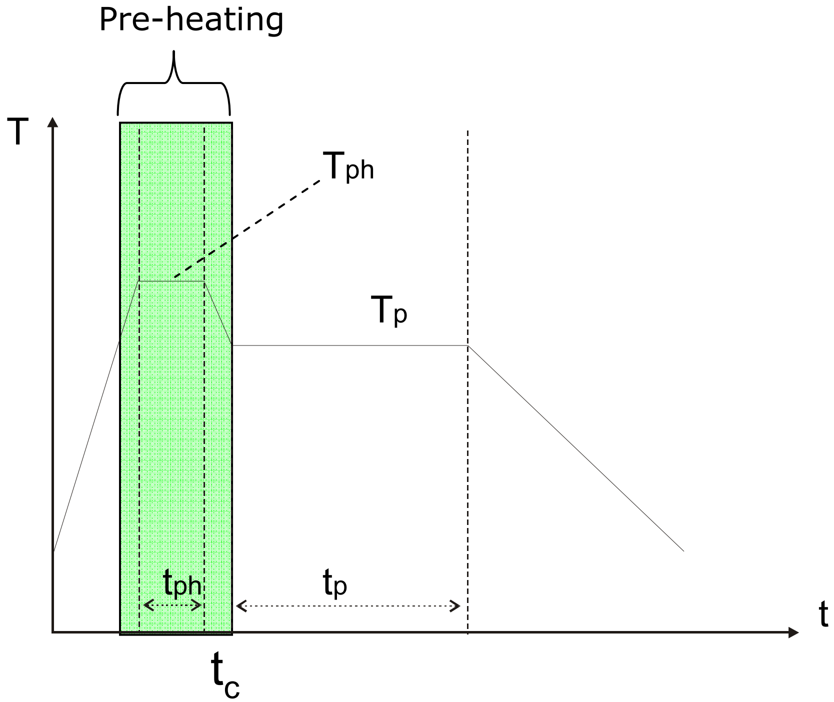
- SH generation on the slopes of pores suggest that dipoles have a specific formation
- In these pores it is easier for ions to recombine with electrons from the ground





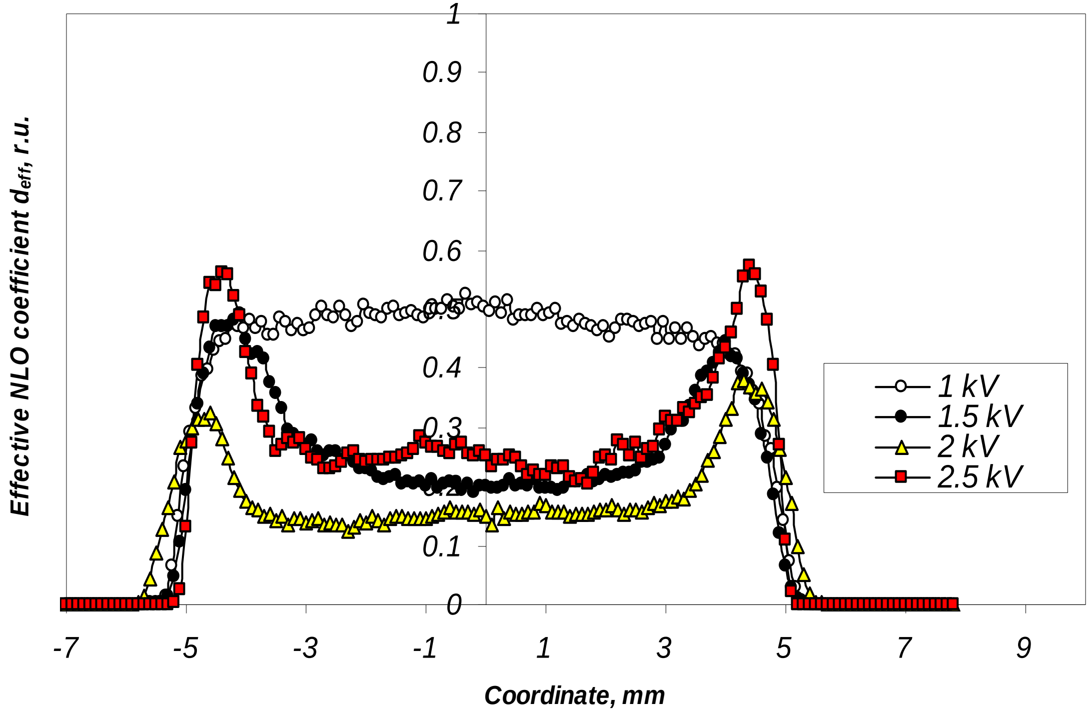
# How to avoid formation of pores

This pre-poling procedure allows one to avoid the formation of pores completely



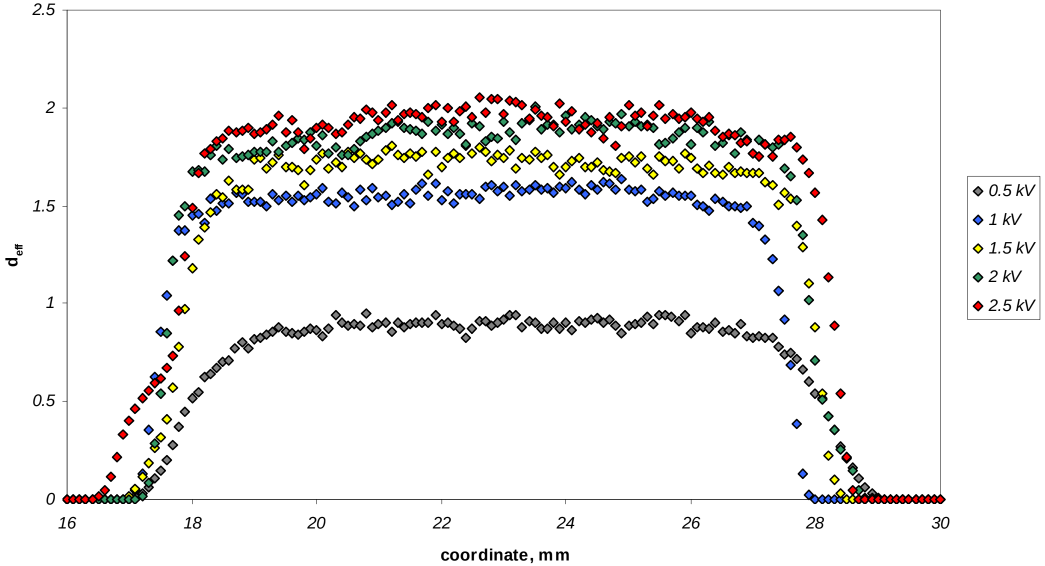

| | | |
|---|---|---|
| $T_{ph}$ | – | Pre-heating temperature |
| $T_p$ | – | Poling temperature |
| $t_c$ | – | Time when the corona voltage is switched on |

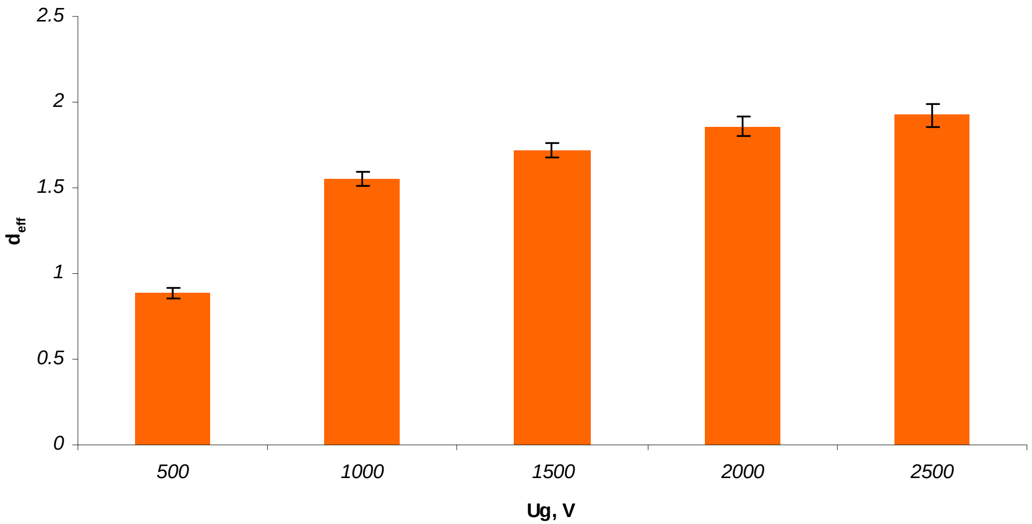
# SHG profiles <u>without</u> pre-poling procedure




- Higher voltage doesnt increase $d_{eff}$
- Total nonlinearity of samples is poor

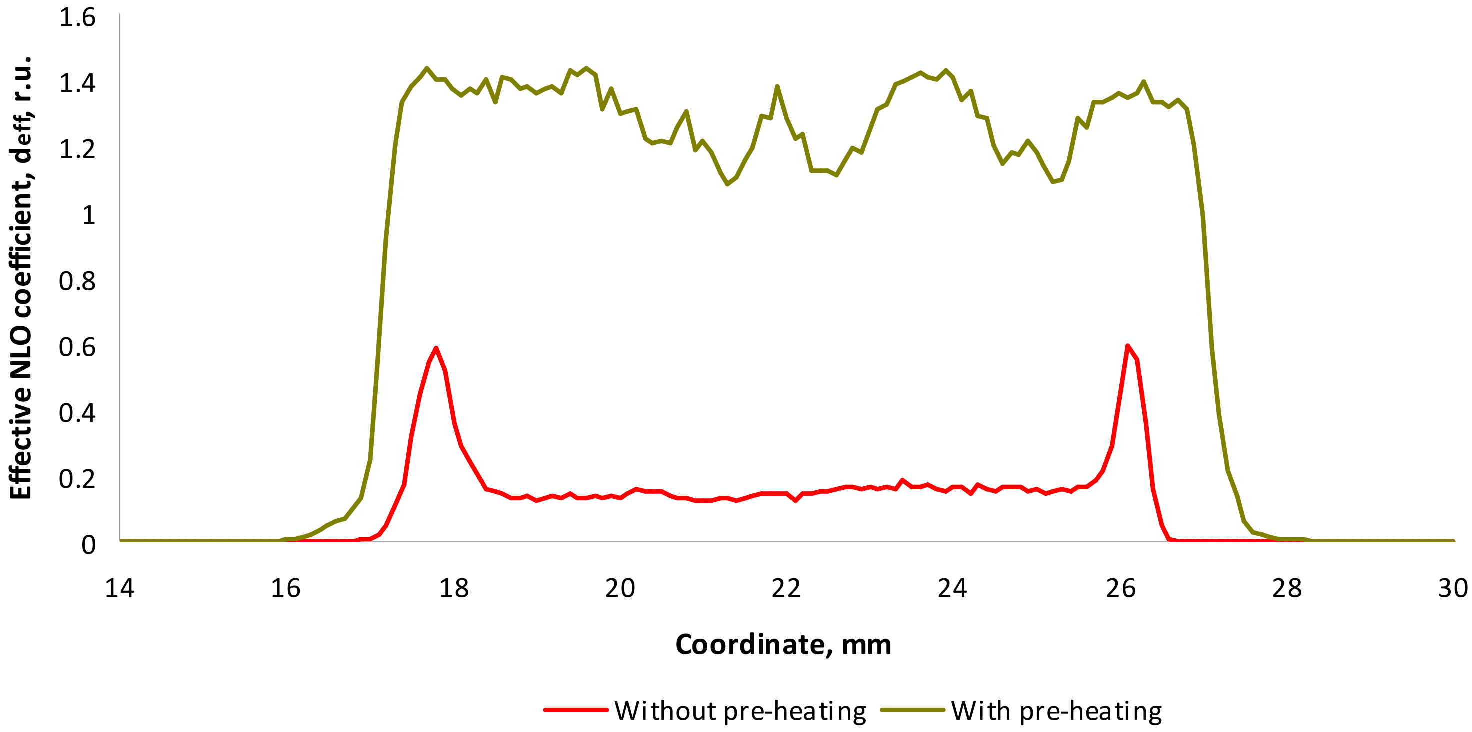
# SHG profiles for samples with pre-poling procedure



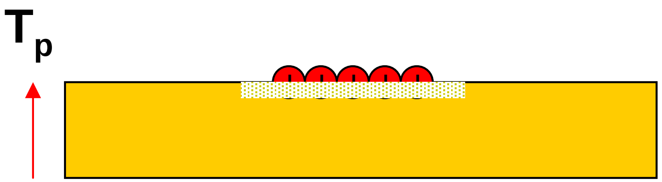



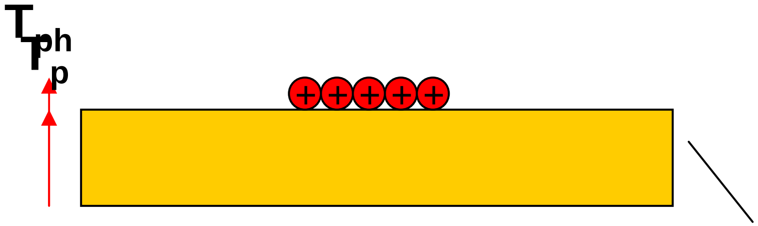

- By increasing the grid voltage, $d_{eff}$ is also increasing
- Total nonlinearity is higher than in the case without pre-heating

# Pre-poling procedure – NLO coefficient is several times higher



# Conclusions




Hardness and $T_g$ increases

Ions have high enough energy to deform polymer film that has not been pre-heated – pours form

Ions have the same energy but polymer hardness has increased – pours dont form

# Conclusions

- The formation of pours happen with the presence of both – high grid potential and temperature close to $T_g$
- Pre-heating rises hardness and $T_g$ of the material
- Pre-heating the sample prior to poling allows one to avoid pours completely
- Pre-poling procedure allows one achieve higher nonlinearity in the samples