



CENTRE FOR ADVANCED LASER TECHNIQUES

Diskretna difrakcija na optički induciranim rešetkama u parama atoma rubidija

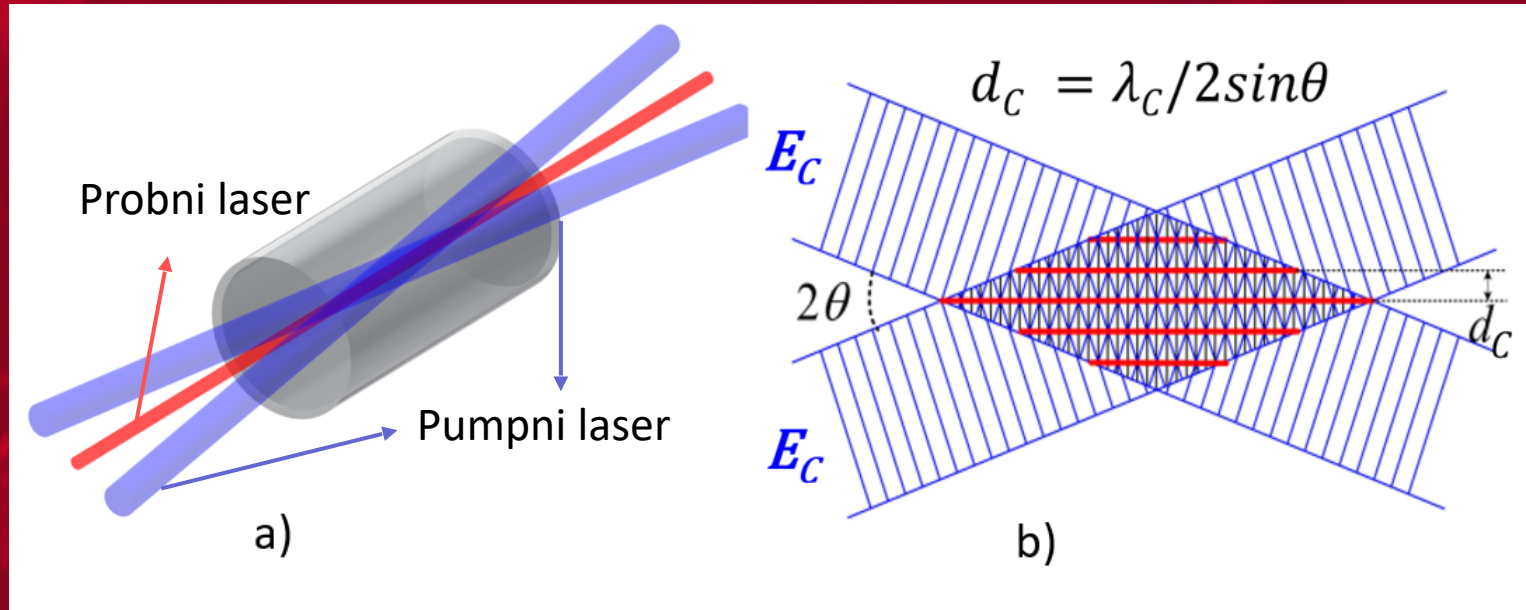
Gabrijela Galić

Mentor: doc. dr. sc. Damir Aumiler

Institut za fiziku, Bijenička cesta 46, 10 000 Zagreb

Projekt je sufinanciran u okviru OP Konkurentnost i kohezija, iz Europskog fonda za regionalni razvoj.

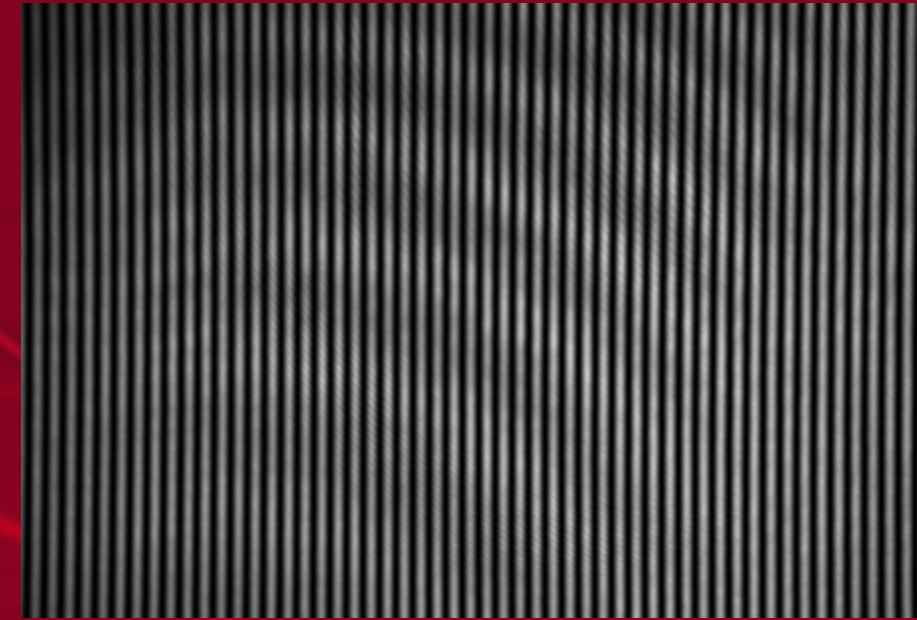
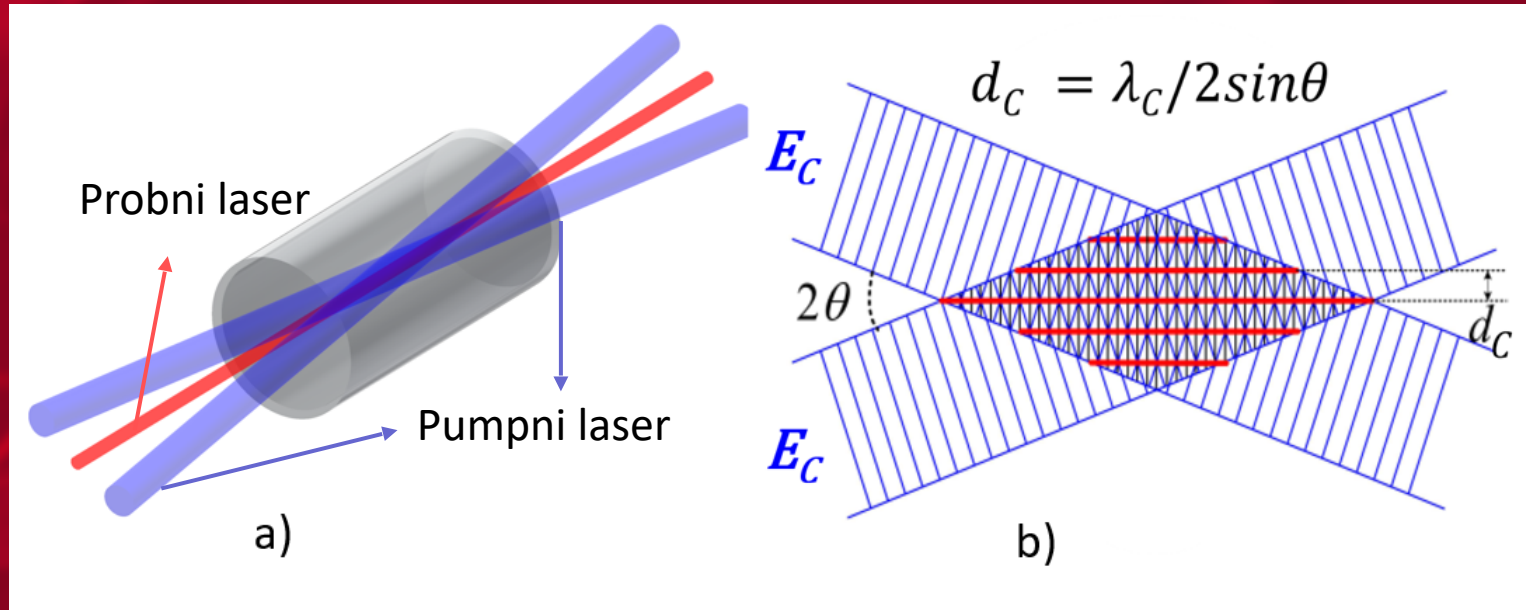
Inducirana rešetka



a) Prikaz prolaska laserskih zraka kroz staklenu ćeliju s parom atoma rubidija.

b) Prikaz interferencije pumpnih laserskih zraka i pojave interferencijskog uzorka.

Inducirana rešetka



a) Prikaz prolaska laserskih zraka kroz staklenu ćeliju s parom atoma rubidija.

Rešetka dobivena interferencijskim zrakama

b) Prikaz interferencije pumpnih laserskih zraka i pojave interferencijskog uzorka.

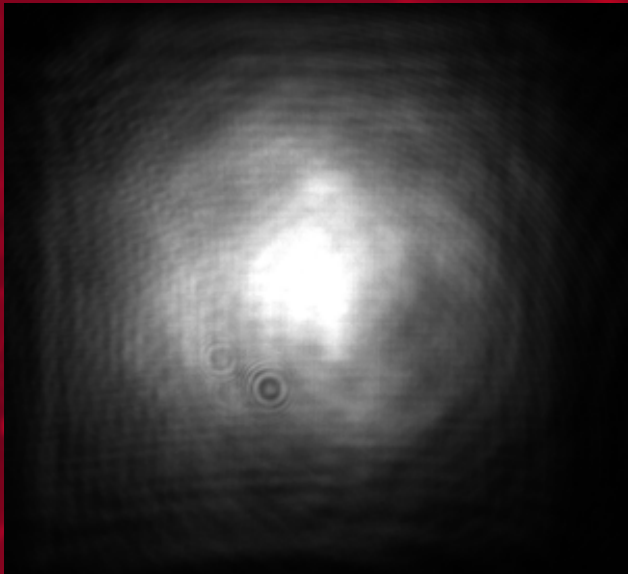
Proba fokusirana na ulazu u staklenu ćeliju



Proba fokusirana na ulazu u staklenu ćeliju



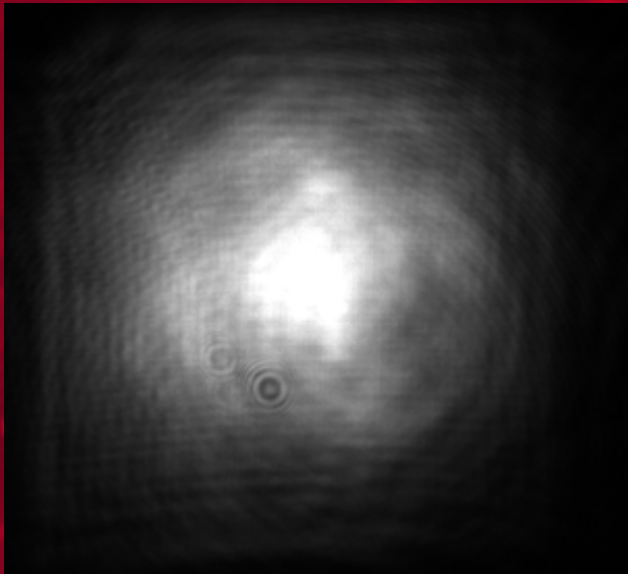
Slika probe bez rešetke na izlazu



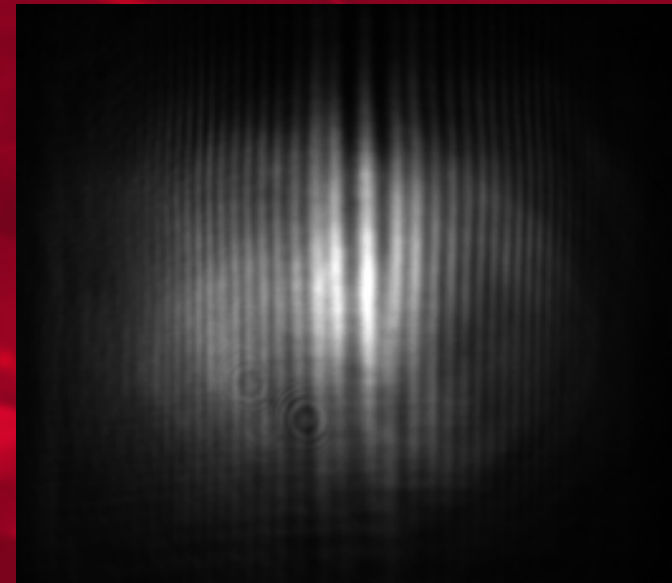
Proba fokusirana na ulazu u staklenu ćeliju



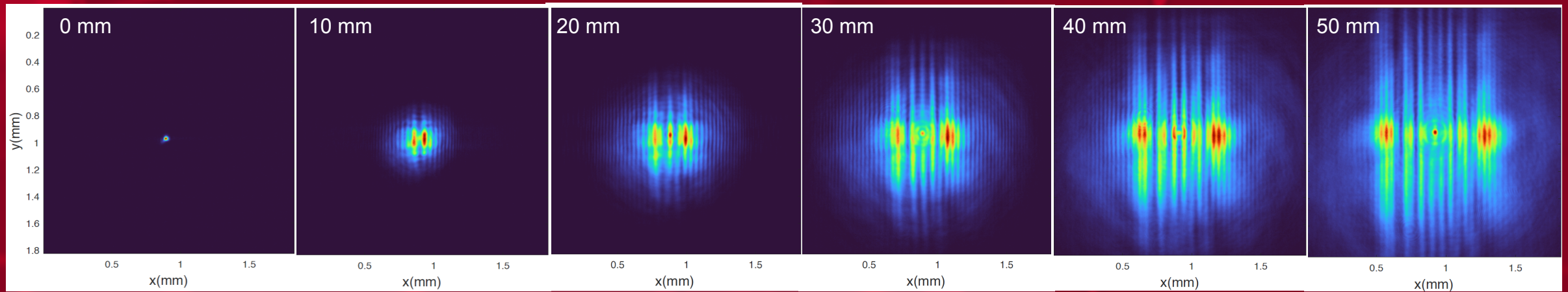
Slika probe bez rešetke na izlazu



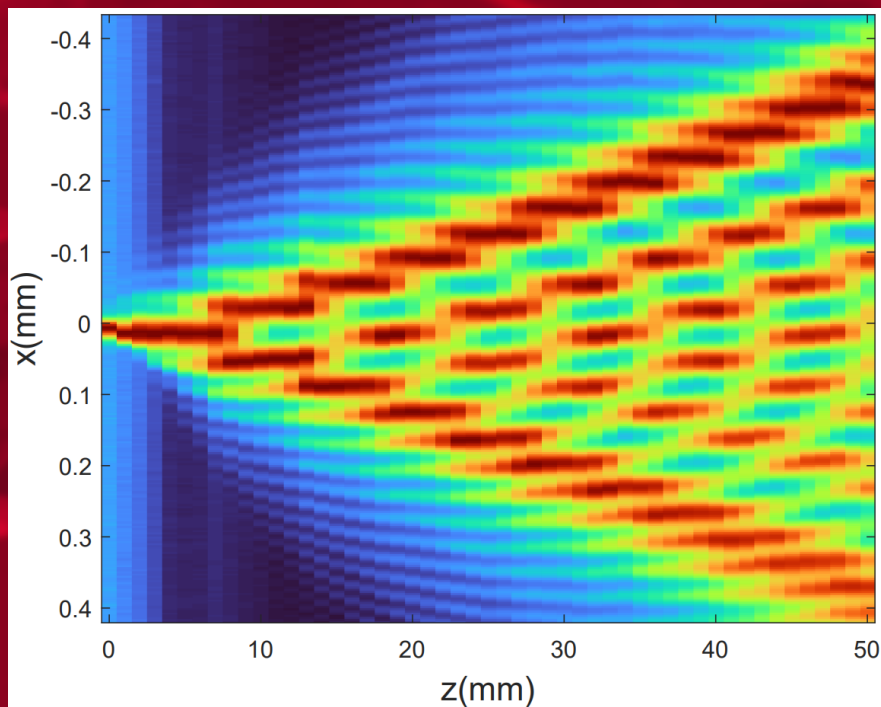
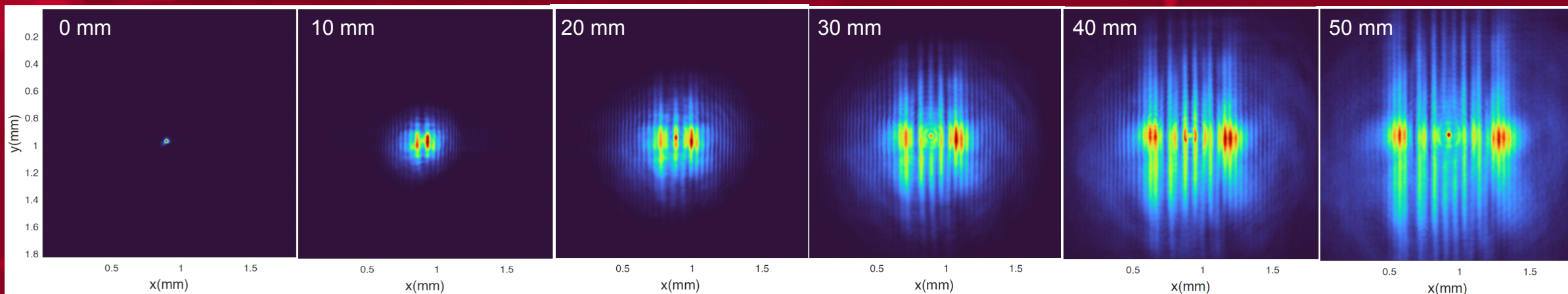
Slika probe s rešetkom na izlazu



Diskretna difrakcija, rešetka = $37\text{ }\mu\text{m}$



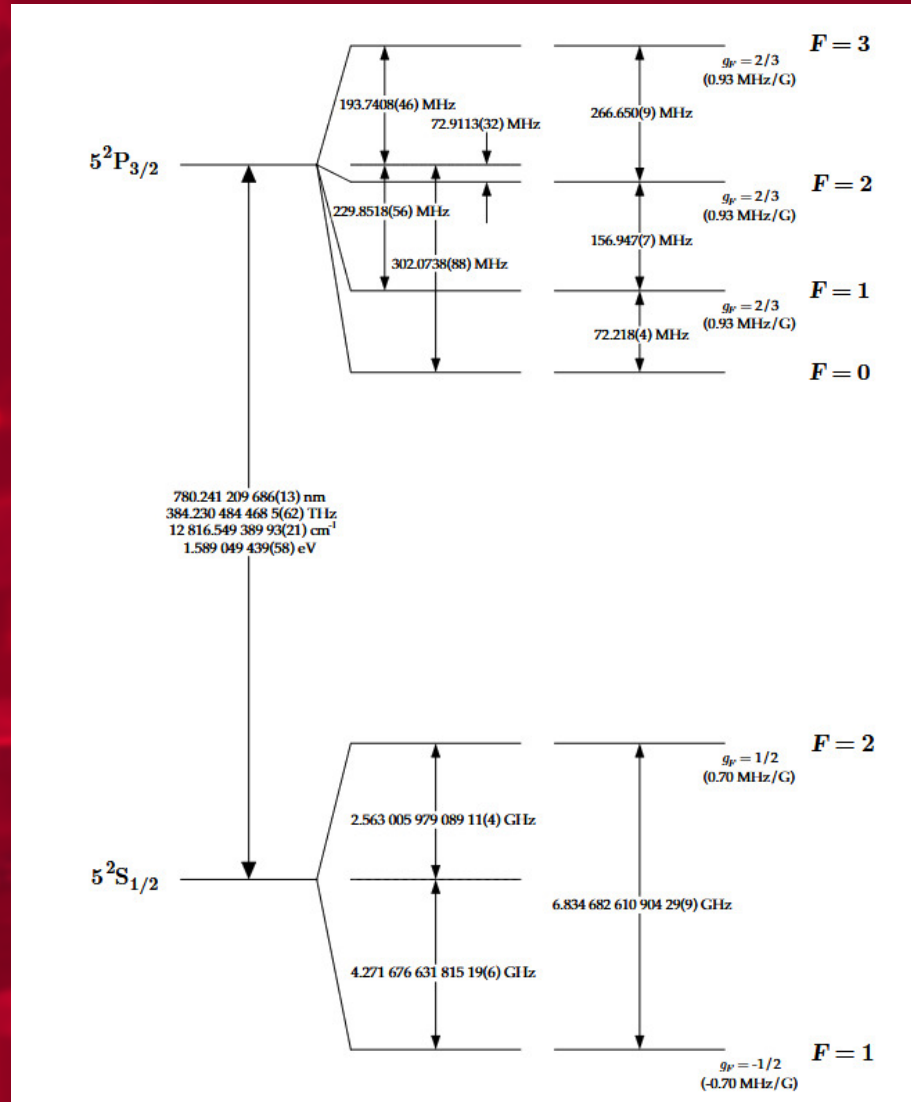
Diskretna difrakcija, rešetka = 37 μm



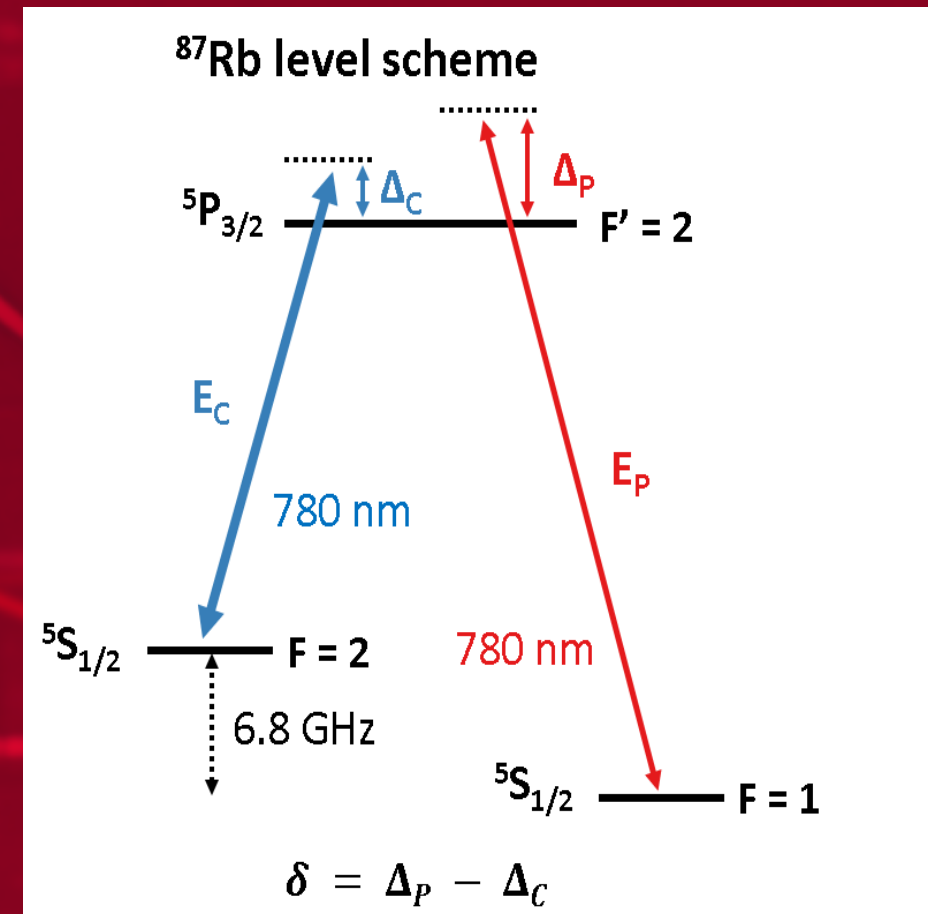
Snaga probnog lasera = 50 μW

Snaga pumpnih lasera = 2 x 100 mW

Rubidij 87



D. A. Steck, Rubidium 87 D Line Data (2004),
<https://steck.us/alkalidata/>



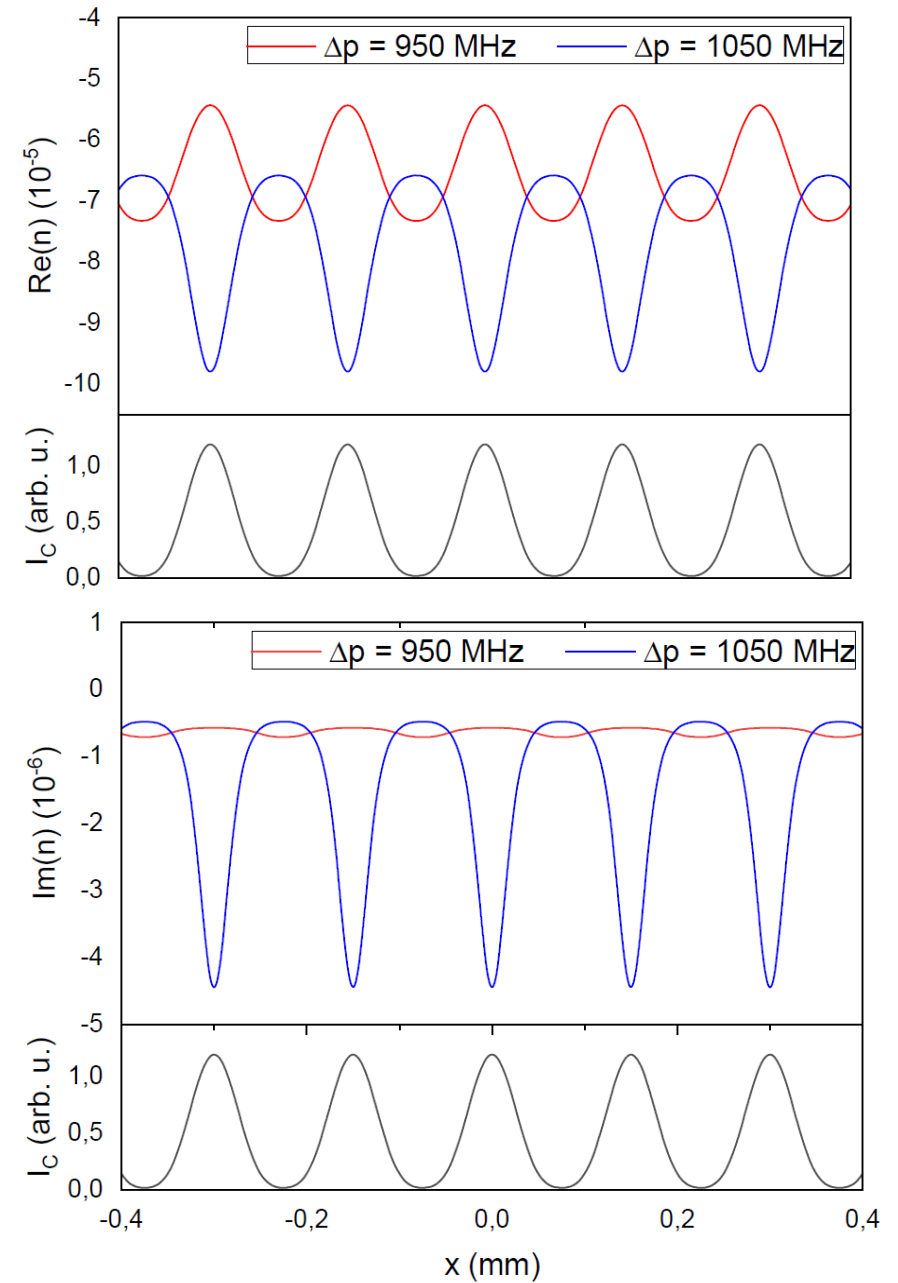
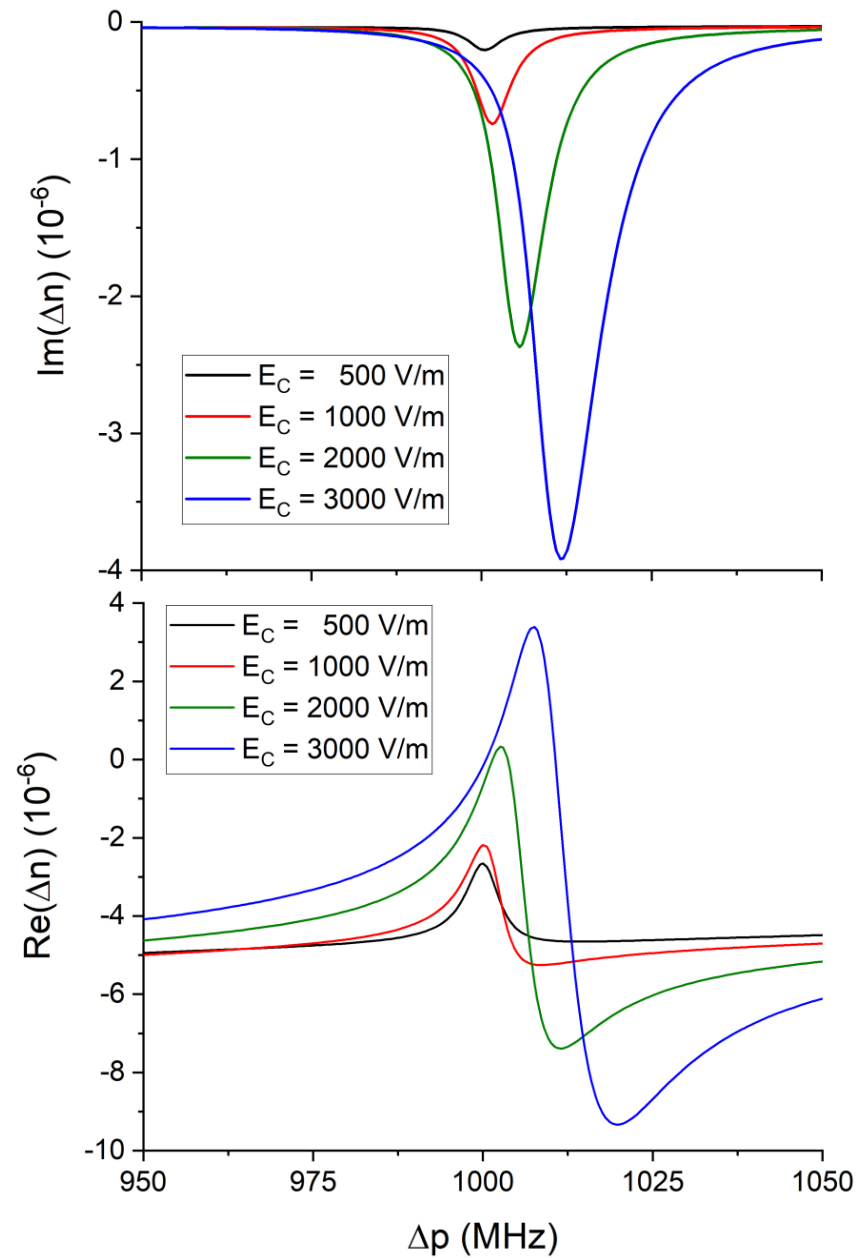
σ_{13}



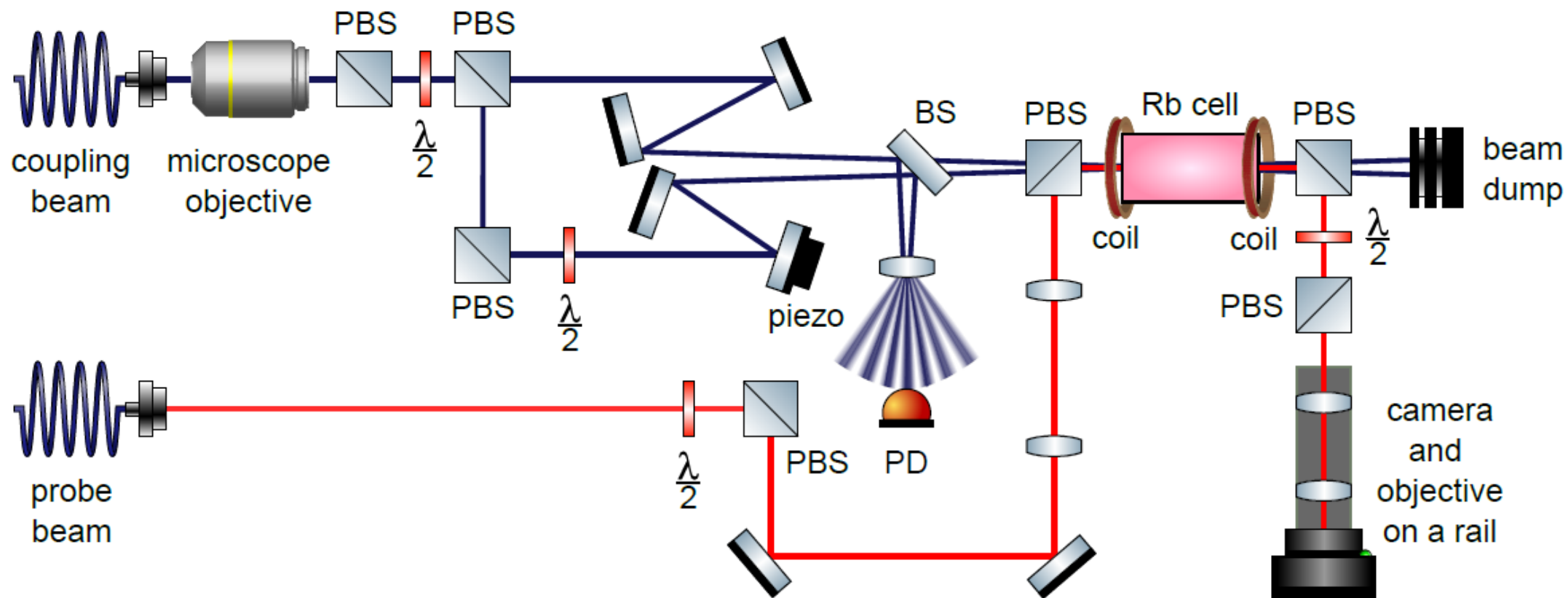
Indeks loma

$$\frac{\partial E_p}{\partial y} = \frac{1}{2ik} \left(\frac{\partial^2 E_p}{\partial x^2} + \frac{\partial^2 E_p}{\partial y^2} \right) - i\Delta n k E_p$$

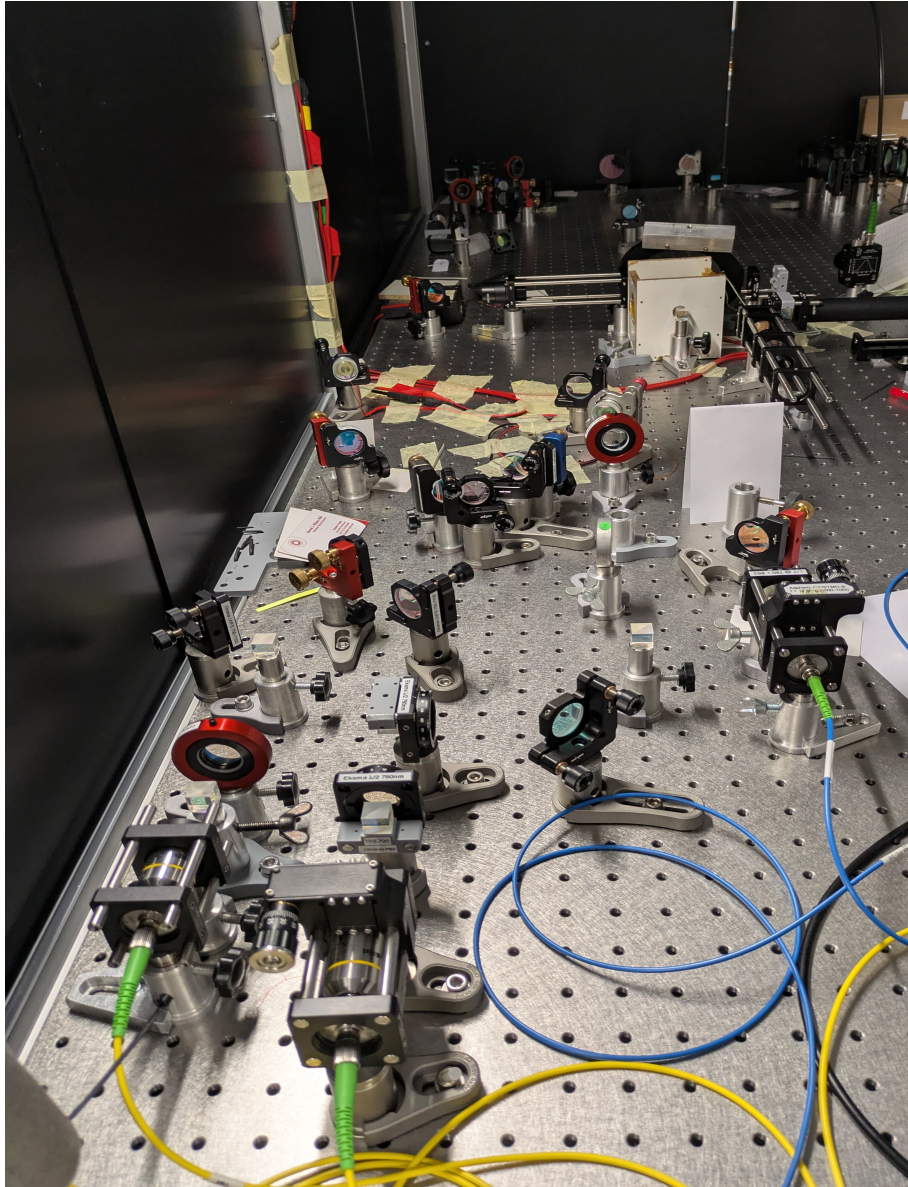
Indeks loma



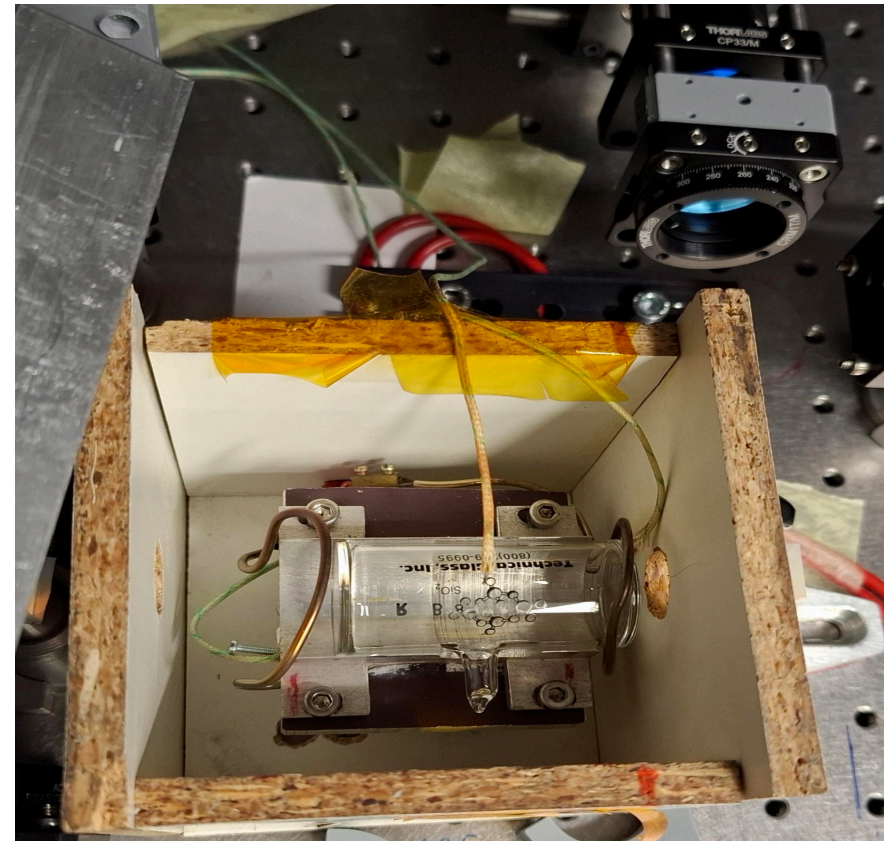
Eksperimentalni postav



Eksperimentalni postav



Staklena ćelija s atomima rubidija



Rezultati

Diskretna difrakcija, rešetka = $37\text{ }\mu\text{m}$, $\Delta_p - \Delta_C = 80\text{ MHz}$

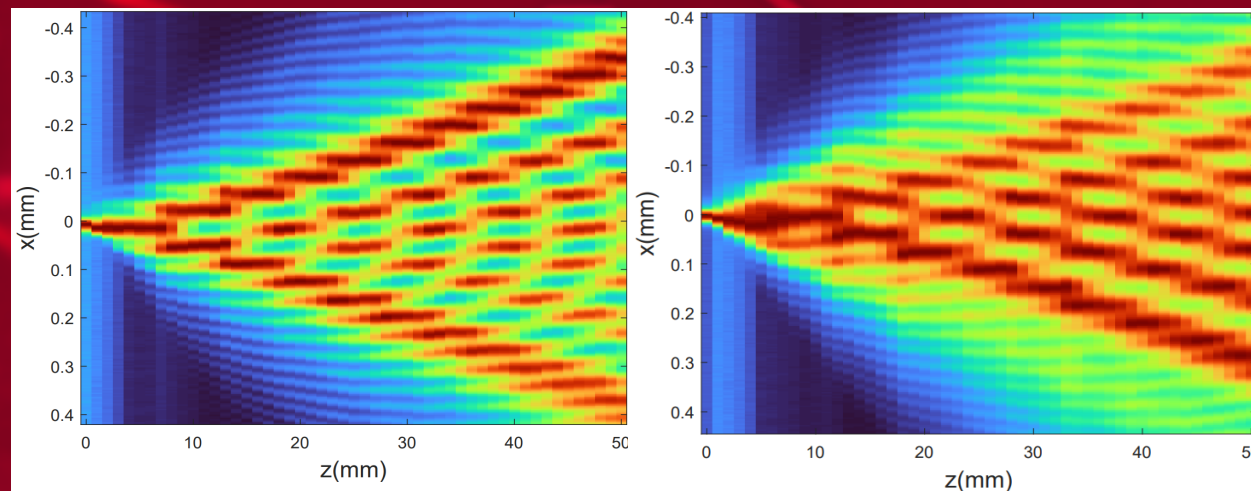
Snaga probnog lasera = $50\text{ }\mu\text{W}$

Snaga pumpnih lasera = $2 \times 100\text{ mW}$

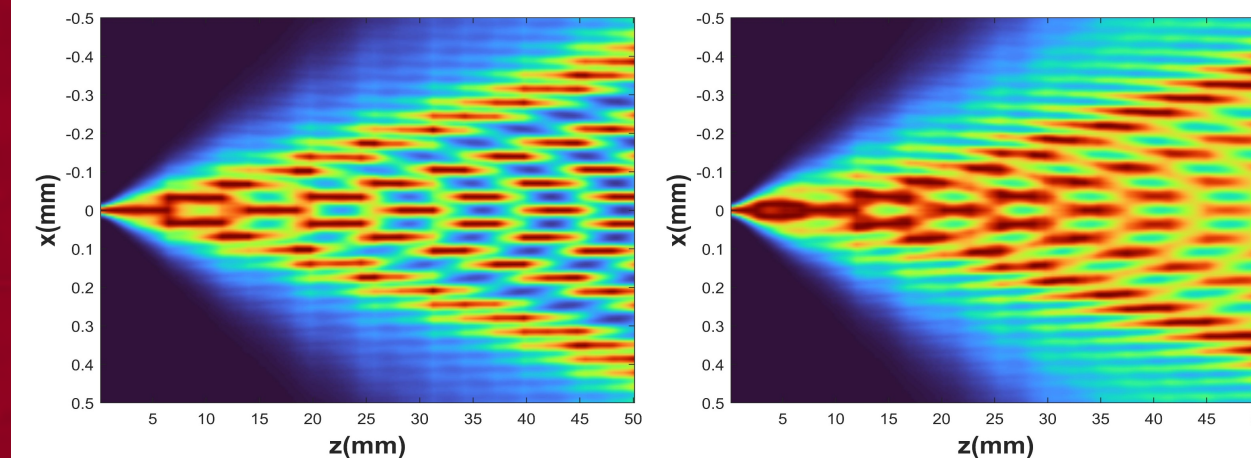
Tamna pruga

Svijetla pruga

Eksperimentalni rezultati



Numeričke simulacije



Rezultati

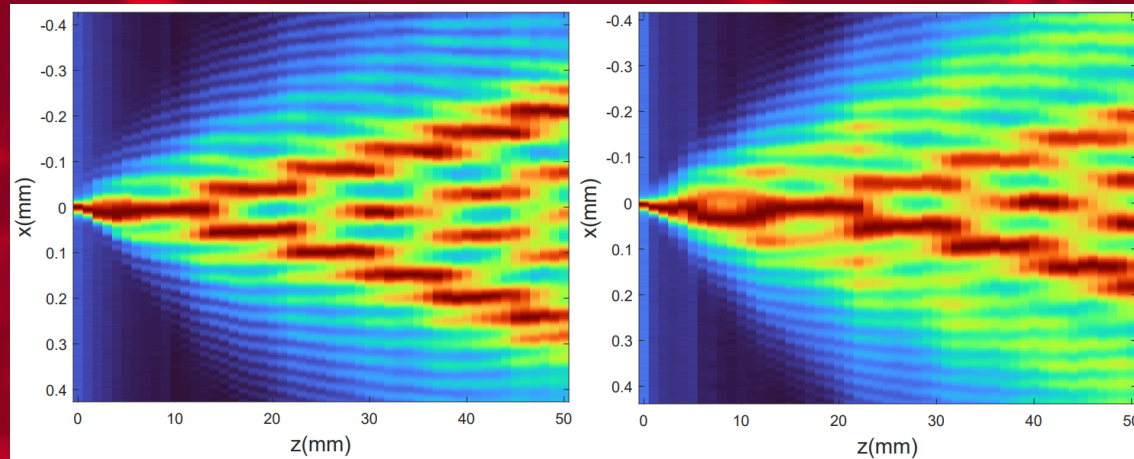
Diskretna difrakcija, rešetke 37 i 47 μm , $\Delta_p - \Delta_C = 80 \text{ MHz}$

Snaga probnog lasera = 50 μW

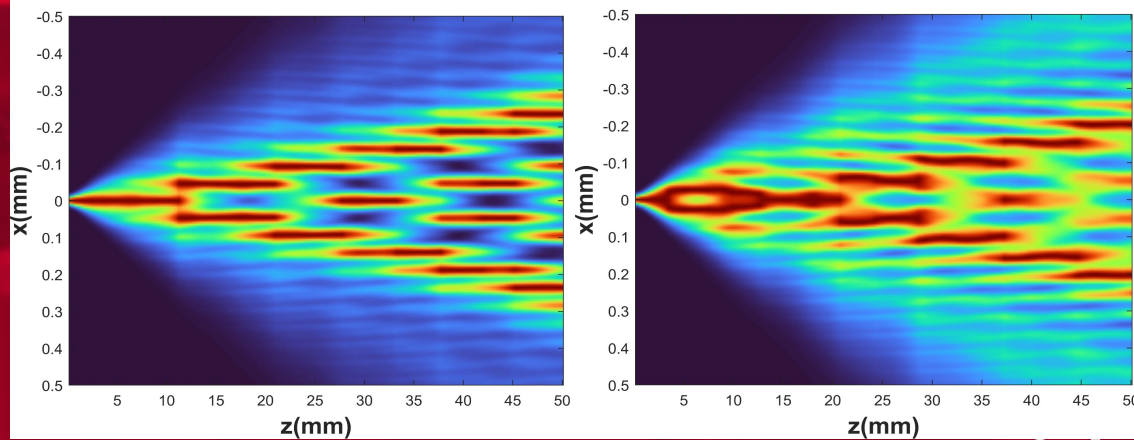
Snaga pumpnih lasera = 2 x 100 mW

47 μm

Izmjereno



Simulacije



Rezultati

Diskretna difrakcija, rešetke 37 i 47 μm , $\Delta_p - \Delta_C = 80 \text{ MHz}$

Snaga probnog lasera = 50 μW

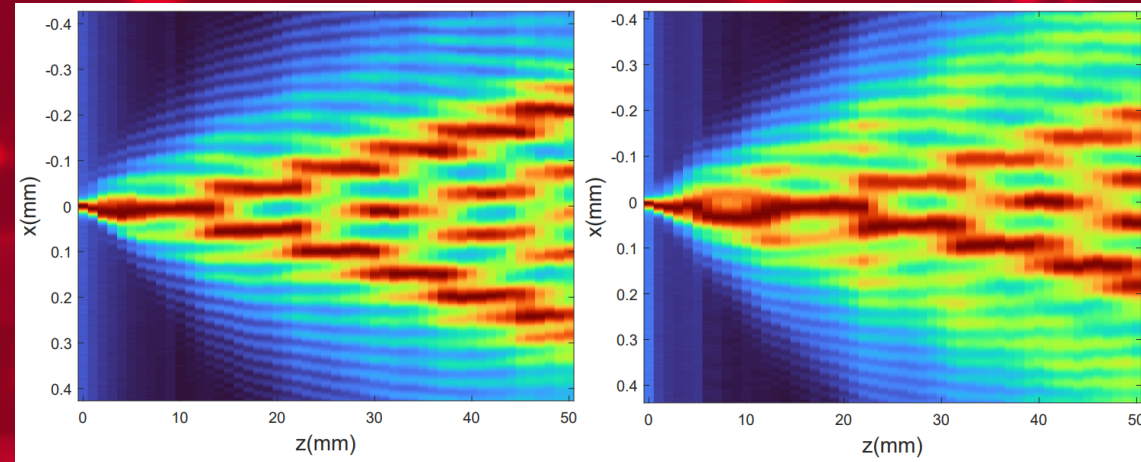
Snaga pumpnih lasera = 2 x 100 mW

47 μm

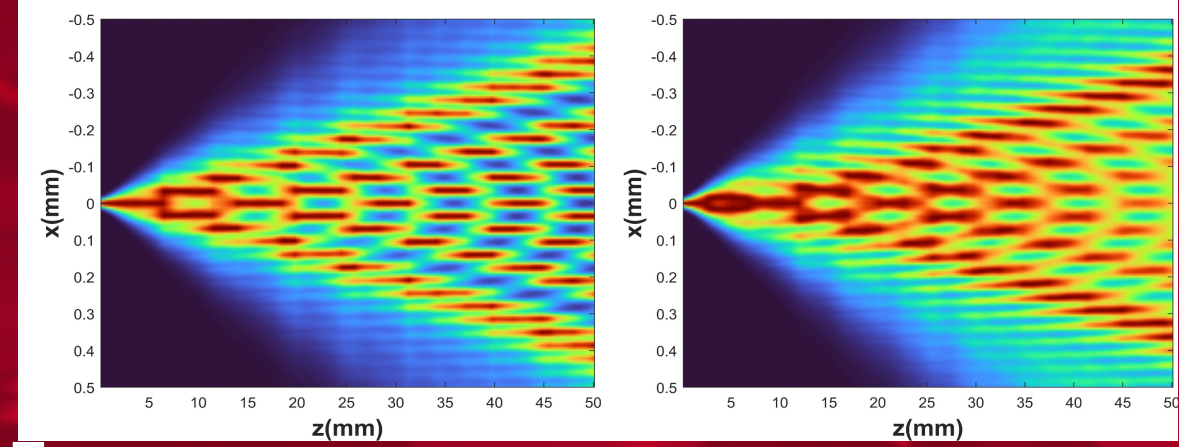
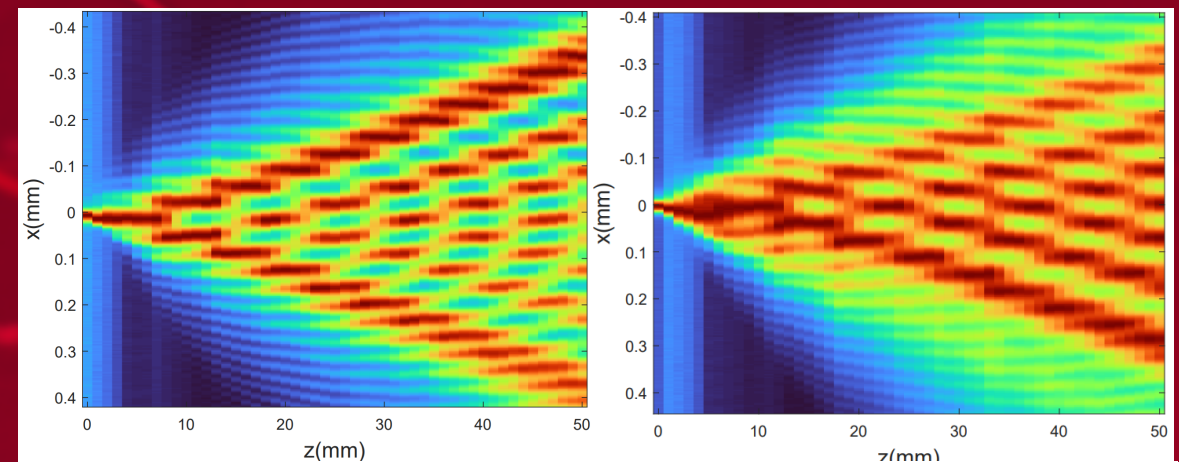
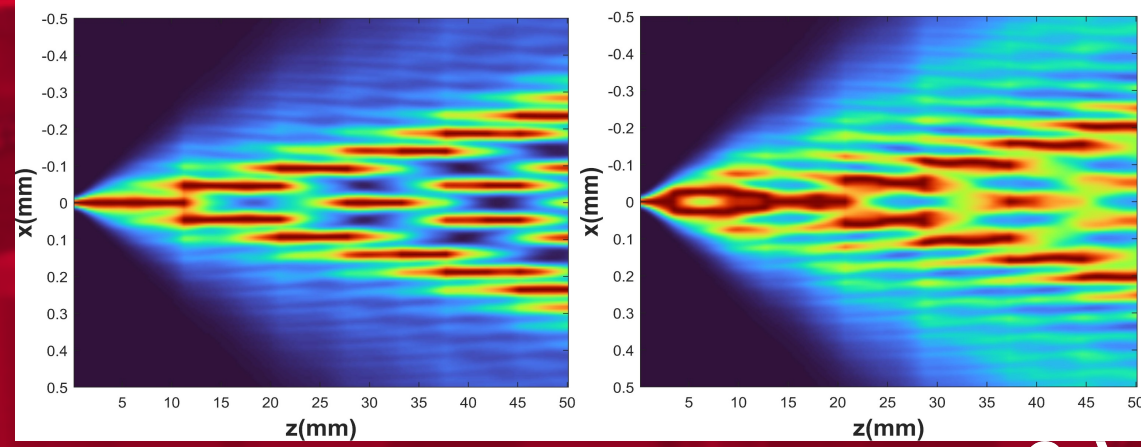
&

37 μm

Izmjereno



Simulacije



Rezultati

Fokusiranje probe u svijetlu prugu rešetke 140 μm

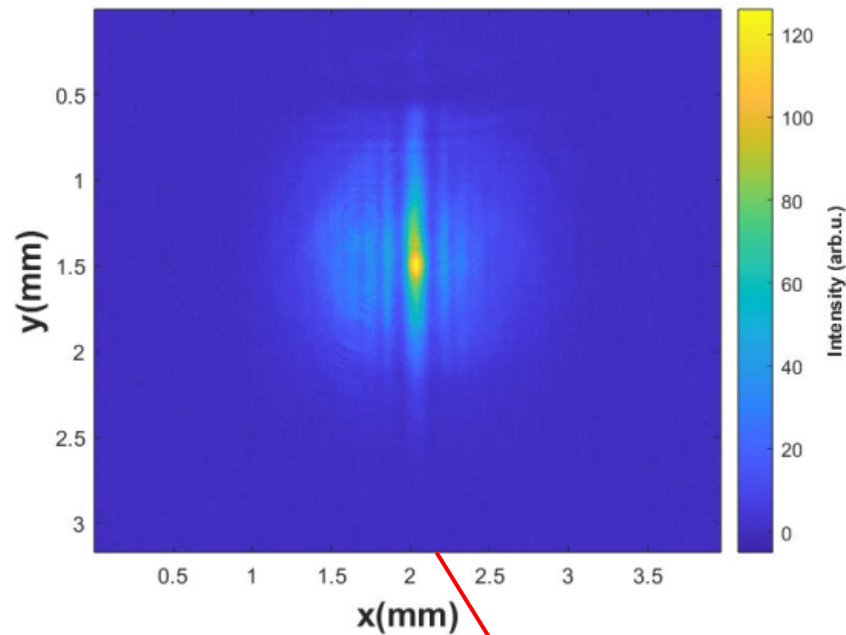
Eksperimentalni rezultati

$$\Delta_C = 1000 \text{ MHz}$$

Snaga probnog lasera = 50 μW

Snaga pumpnih lasera = 2 x 100 mW

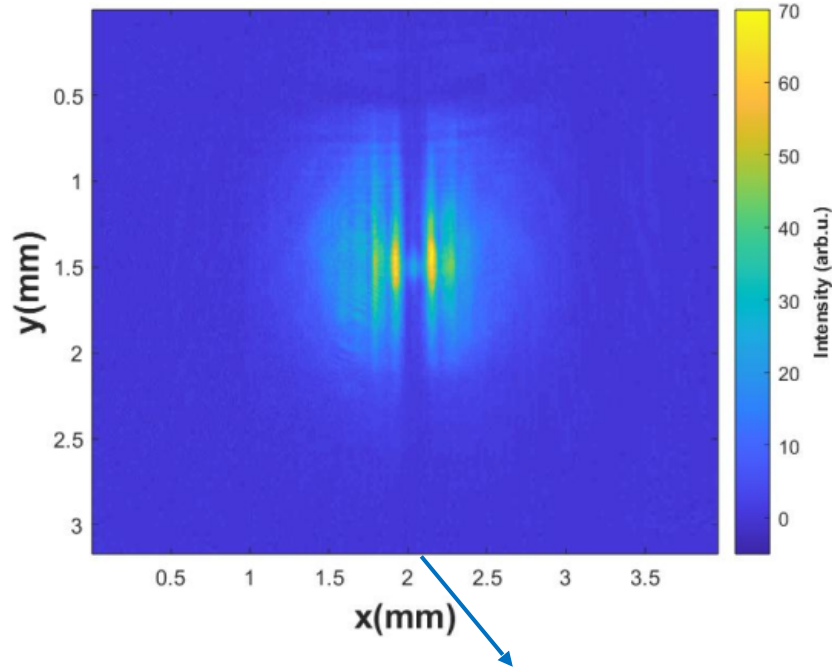
Slika probe na izlazu iz staklene ćelije



Crveni frekventni pomak

$$\Delta_p - \Delta_C = -9 \text{ MHz}$$

Slika probe na izlazu iz staklene ćelije



Plavi frekventni pomak

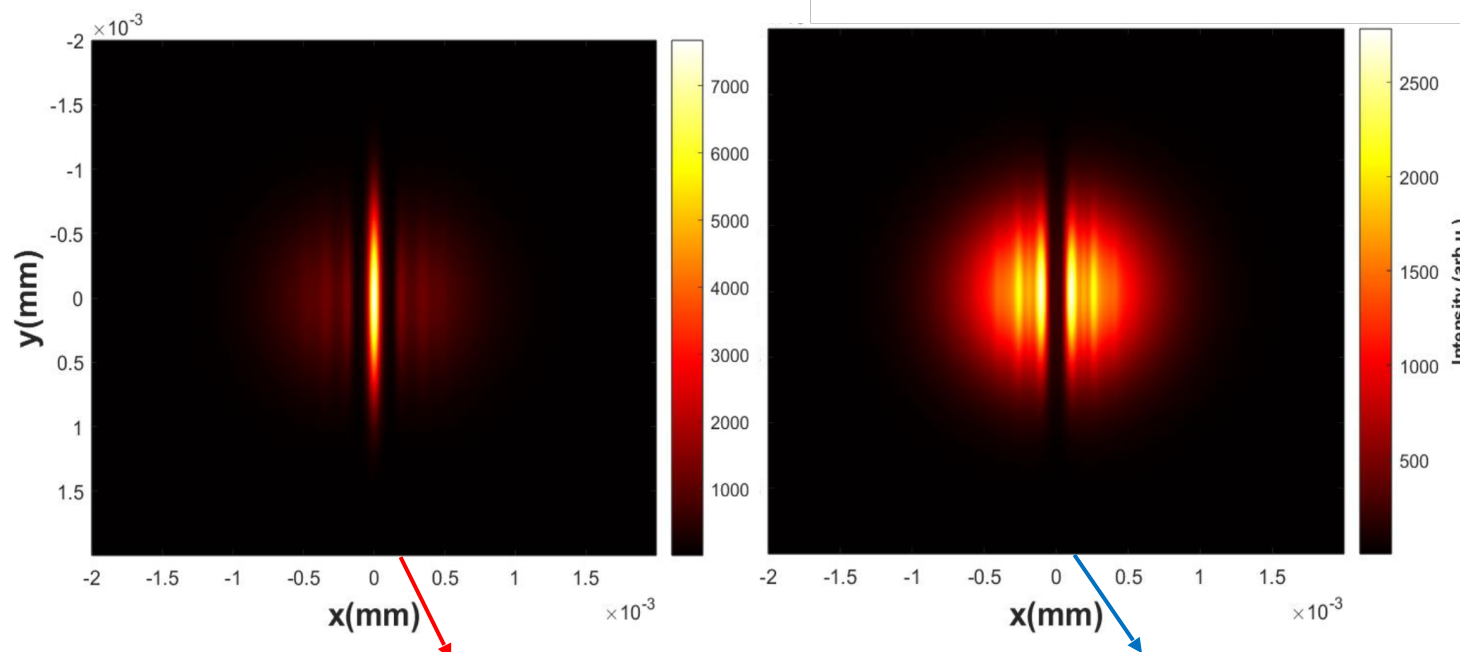
$$\Delta_p - \Delta_C = 61 \text{ MHz}$$

Rezultati

Fokusiranje probe u svijetlu prugu rešetke 140 μm

Numeričke simulacije

Izgled probe na izlazu iz staklene ćelije



Crveni frekventni pomak

$$\Delta_p - \Delta_C = -50 \text{ MHz}$$

Plavi frekventni pomak

$$\Delta_p - \Delta_C = 50 \text{ MHz}$$

$$\Delta_C = 1000 \text{ MHz}$$

Snaga probnog lasera = 50 μW

Snaga pumpnih lasera = 2 x 100 mW

Rezultati

Fokusiranje probe u tamnu prugu rešetke 140 μm

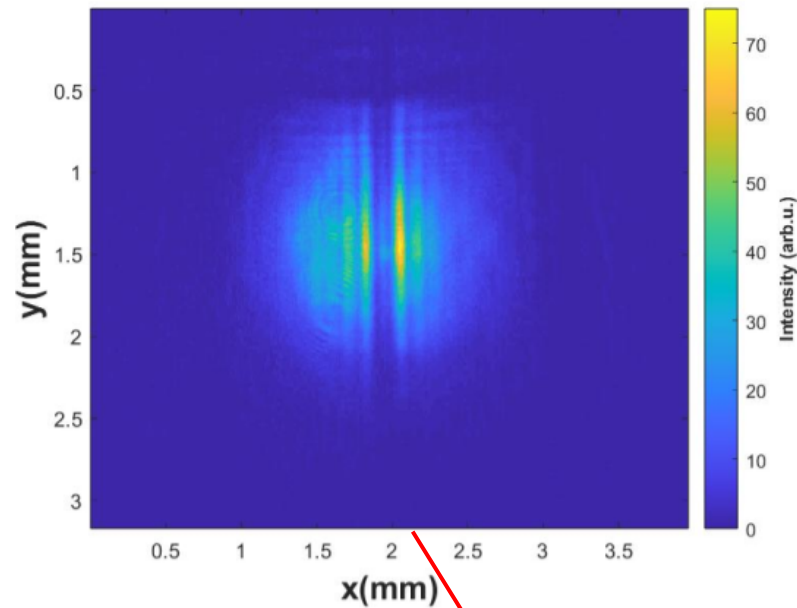
Eksperimentalni rezultati

$$\Delta_C = 1000 \text{ MHz}$$

Snaga probnog lasera = 50 μW

Snaga pumpnih lasera = 2 x 100 mW

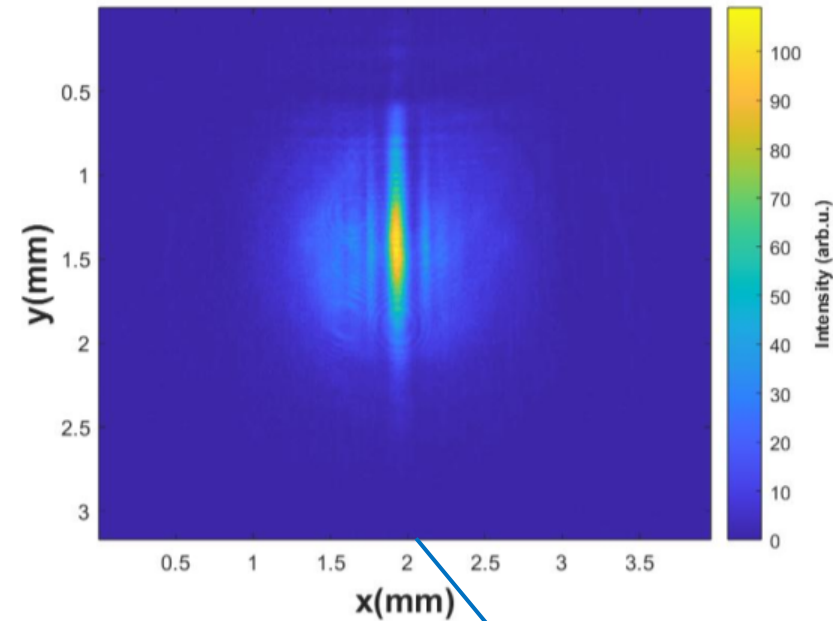
Slika probe na izlazu iz staklene ćelije



Crveni frekventni pomak

$$\Delta_p - \Delta_C = -9 \text{ MHz}$$

Slika probe na izlazu iz staklene ćelije



Plavi frekventni pomak

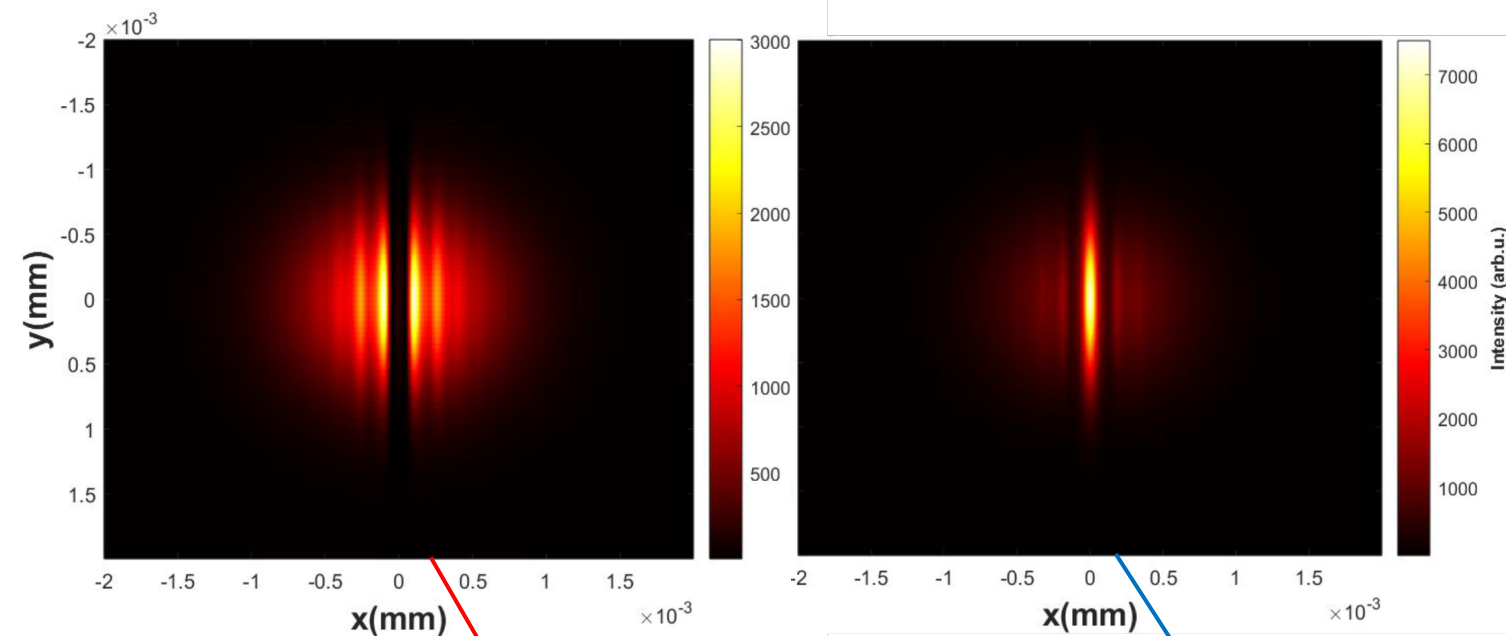
$$\Delta_p - \Delta_C = 61 \text{ MHz}$$

Rezultati

Fokusiranje probe u svijetlu prugu rešetke 140 μm

Numeričke simulacije

Izgled probe na izlazu iz staklene ćelije



Crveni frekventni pomak

$$\Delta_p - \Delta_C = -50 \text{ MHz}$$

Plavi frekventni pomak

$$\Delta_p - \Delta_C = 50 \text{ MHz}$$

$$\Delta_C = 1000 \text{ MHz}$$

Snaga probnog lasera = 50 μW

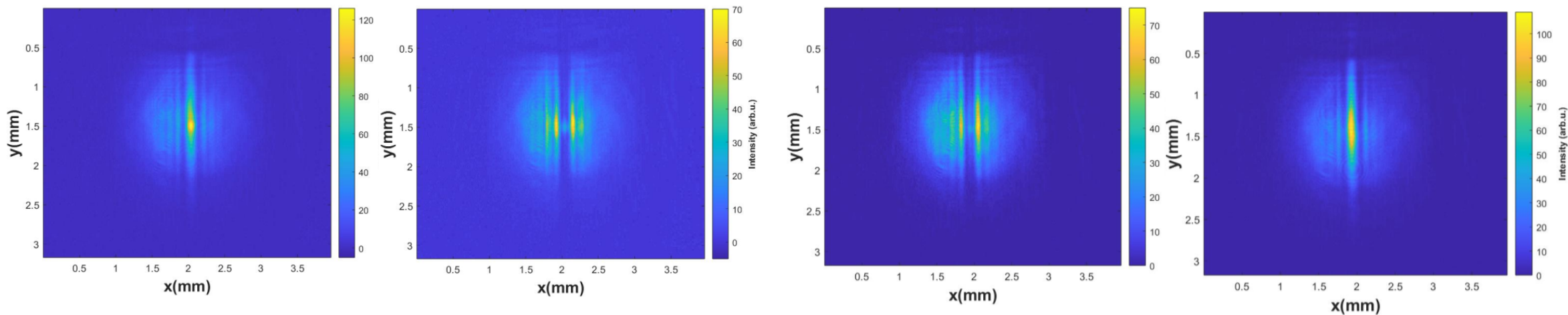
Snaga pumpnih lasera = 2 x 100 mW

Rezultati

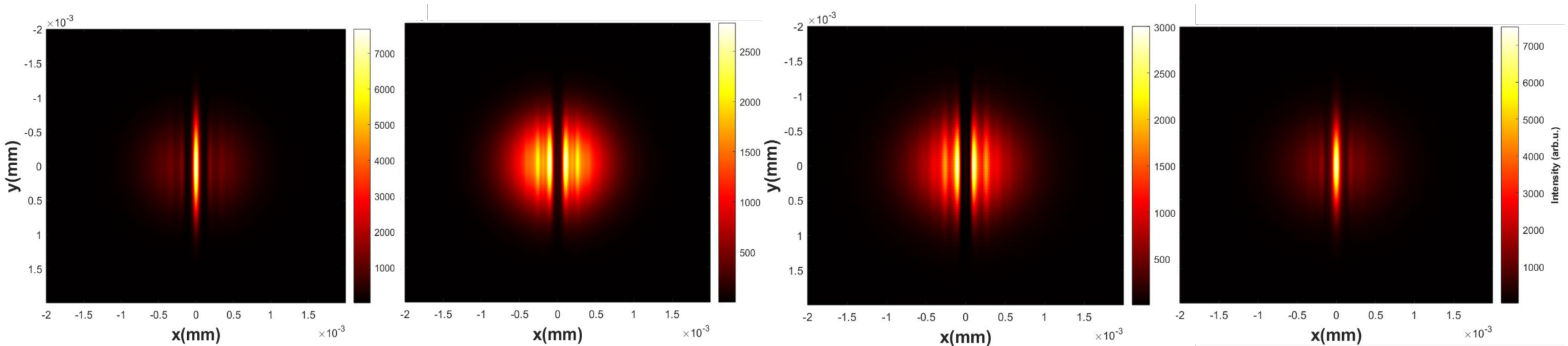
Proba fokusirana u svijetlu prugu

Proba fokusirana u tamnu prugu

Izmjereno



Simulacije



Crveni frekventni pomak

Plavi frekventni pomak

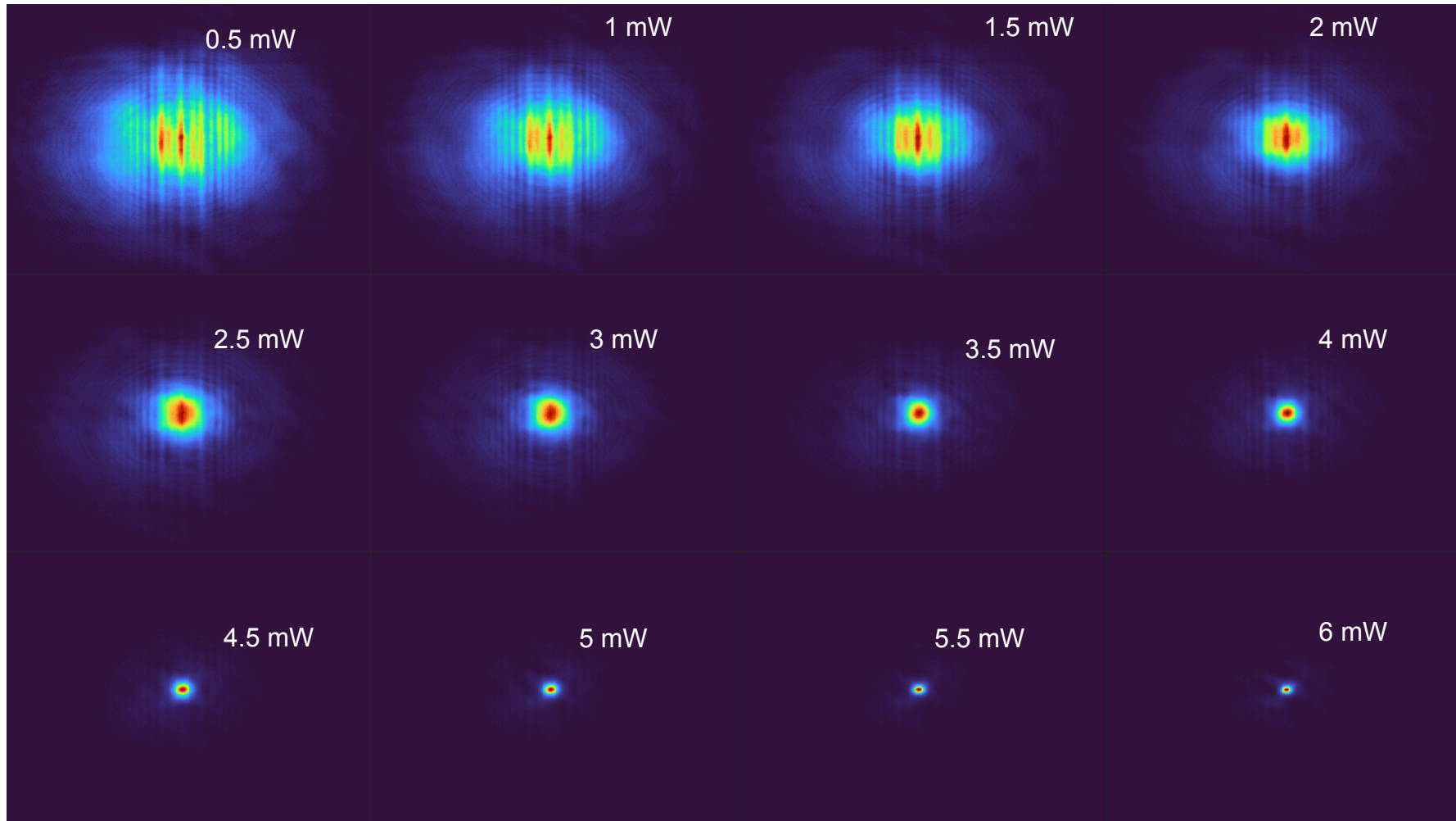
CALT

Crveni frekventni pomak

Plavi frekventni pomak

Rezultati

Diskretni solitoni, dvofotonski frekventni pomak na - 40 MHz



- Diskretna difrakcija
- Apsorpcija
- Solitonsko ponašanje

Diskretni solitoni

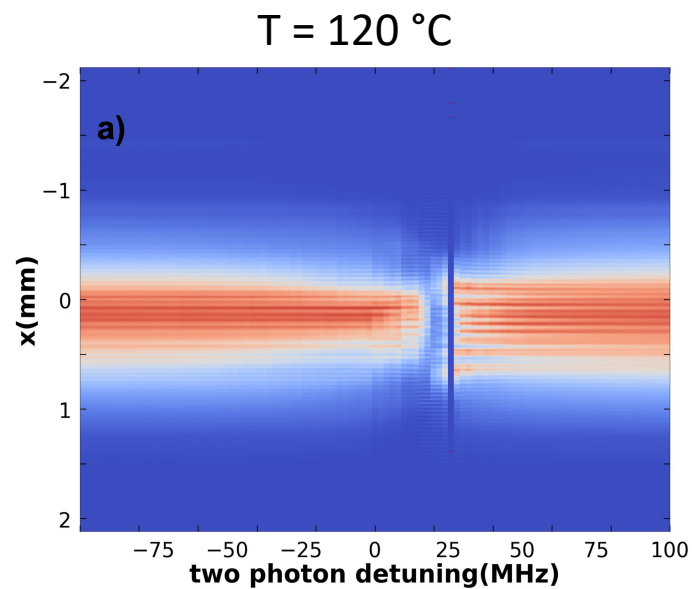
Slike probe na izlazu iz staklene ćelije u ovisnosti o dvofotonskom pomaku

Snaga probnog lasera = 1.5 mW

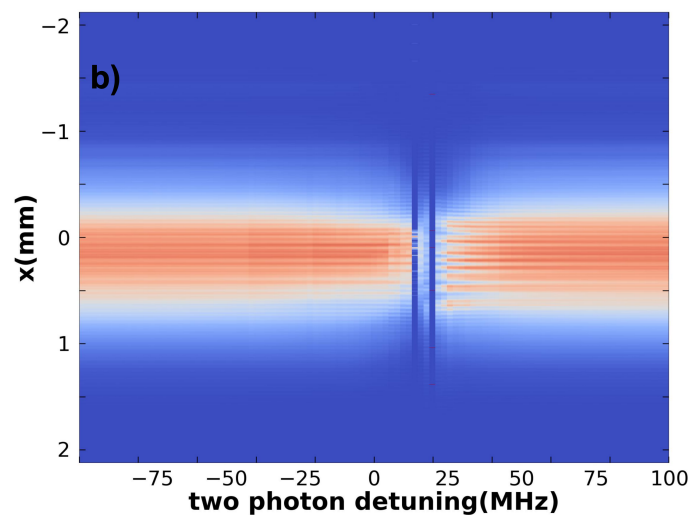
Snaga pumpnih lasera = 2 x 200 mW

Veličina rešetke = 35 μm

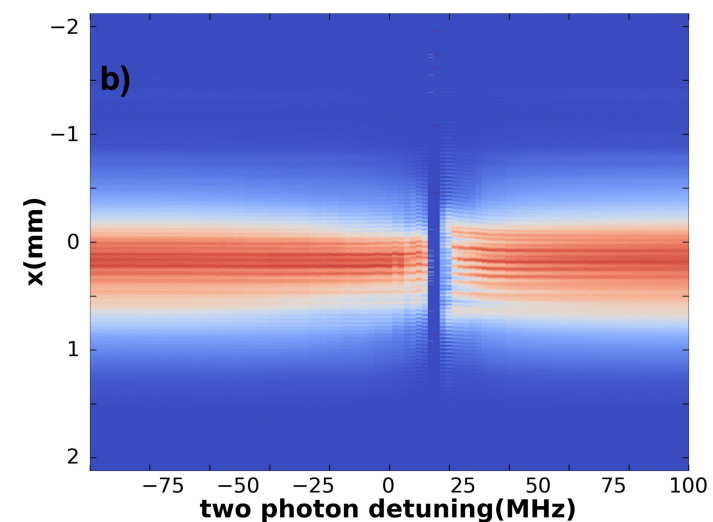
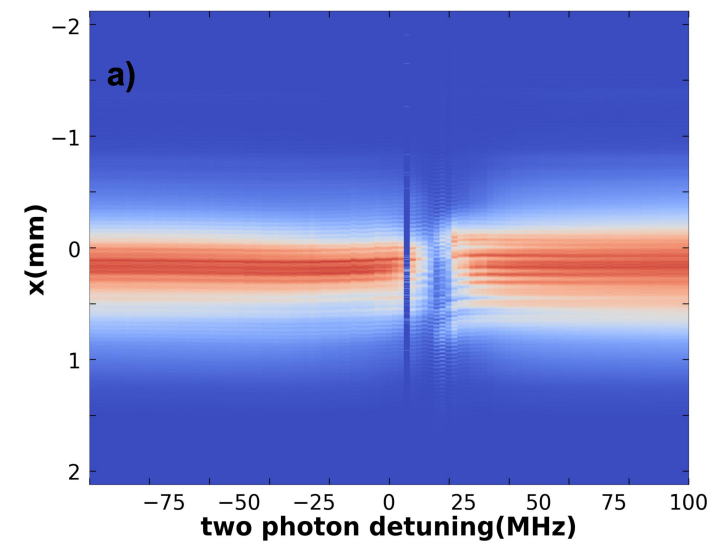
$$\Delta_C = 1100 \text{ MHz}$$



$$\Delta_C = 1300 \text{ MHz}$$



T = 100 °C



Diskretni solitoni

Slike probe na izlazu iz staklene ćelije u ovisnosti o dvofotonskom pomaku

Snaga probnog lasera = 6 mW

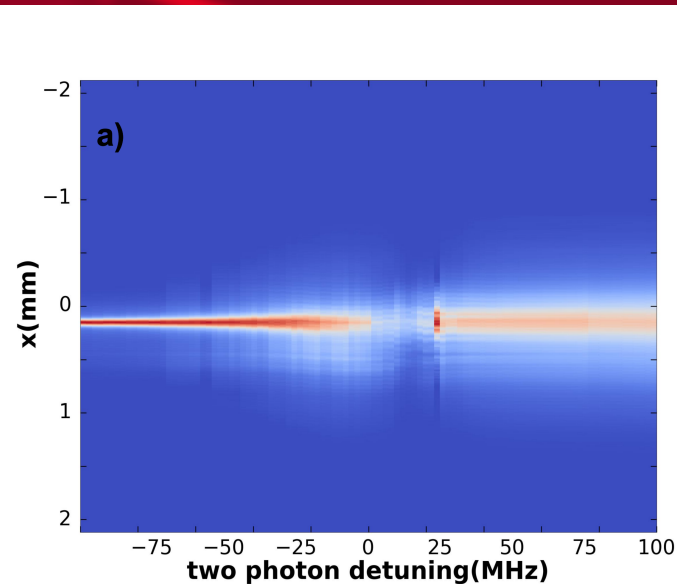
Snaga pumpnih lasera = 2 x 200 mW

Veličina rešetke = 35 μm

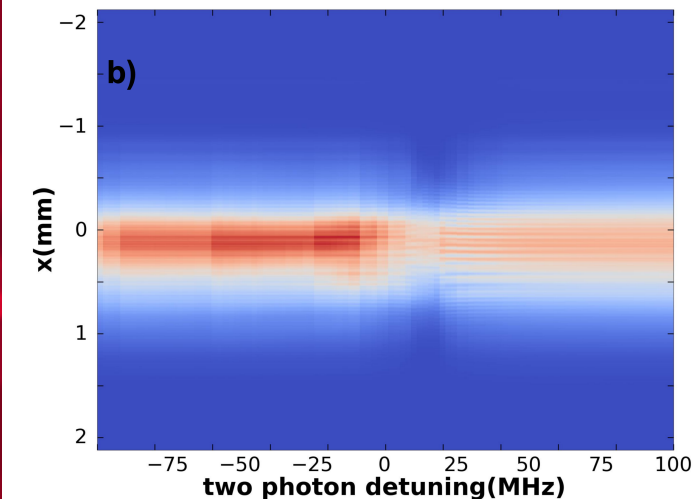
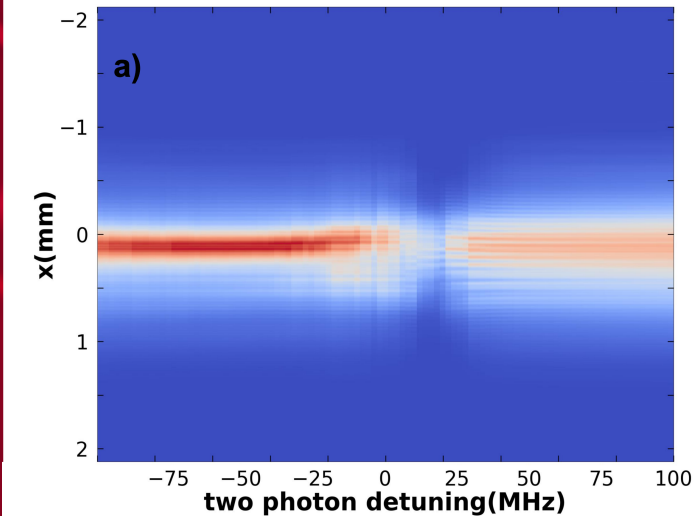
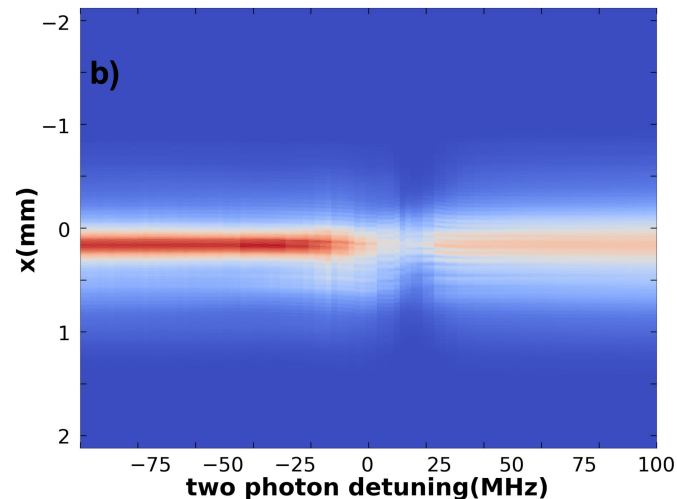
$T = 120\text{ }^{\circ}\text{C}$

$T = 100\text{ }^{\circ}\text{C}$

$\Delta_C = 1100\text{ MHz}$



$\Delta_C = 1300\text{ MHz}$



Diskretni solitoni

Slike probe na izlazu iz staklene ćelije u ovisnosti o dvofotonskom pomaku

Snaga probnog lasera = 20 mW

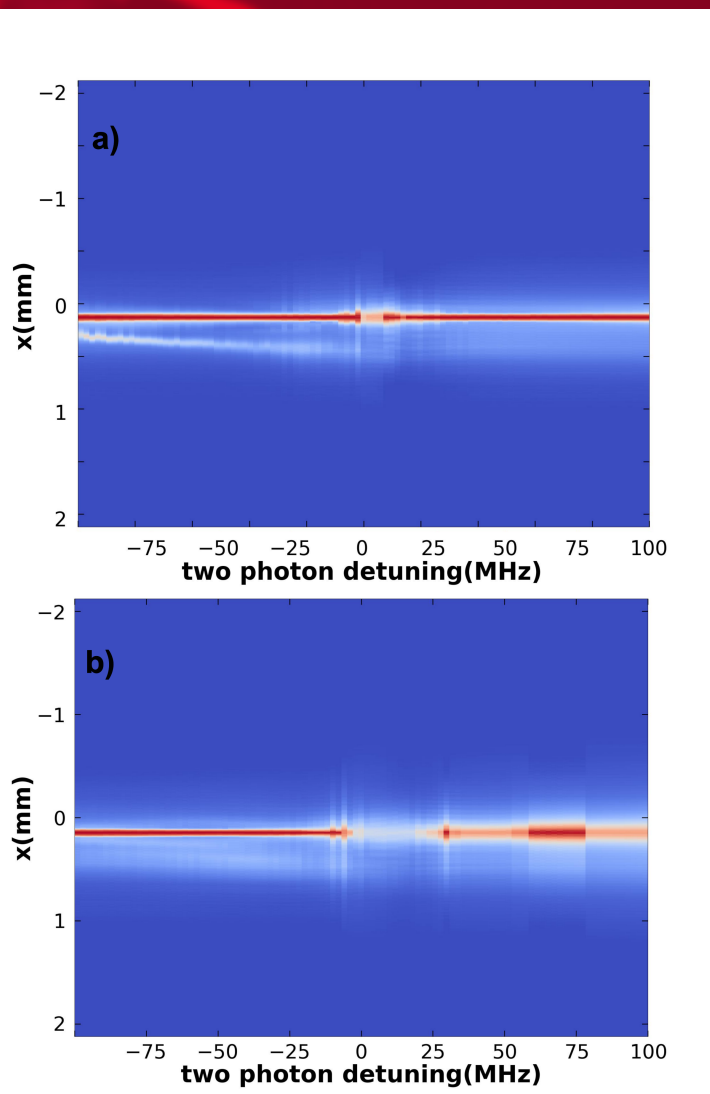
Snaga pumpnih lasera = 2 x 200 mW

Veličina rešetke = 35 μm

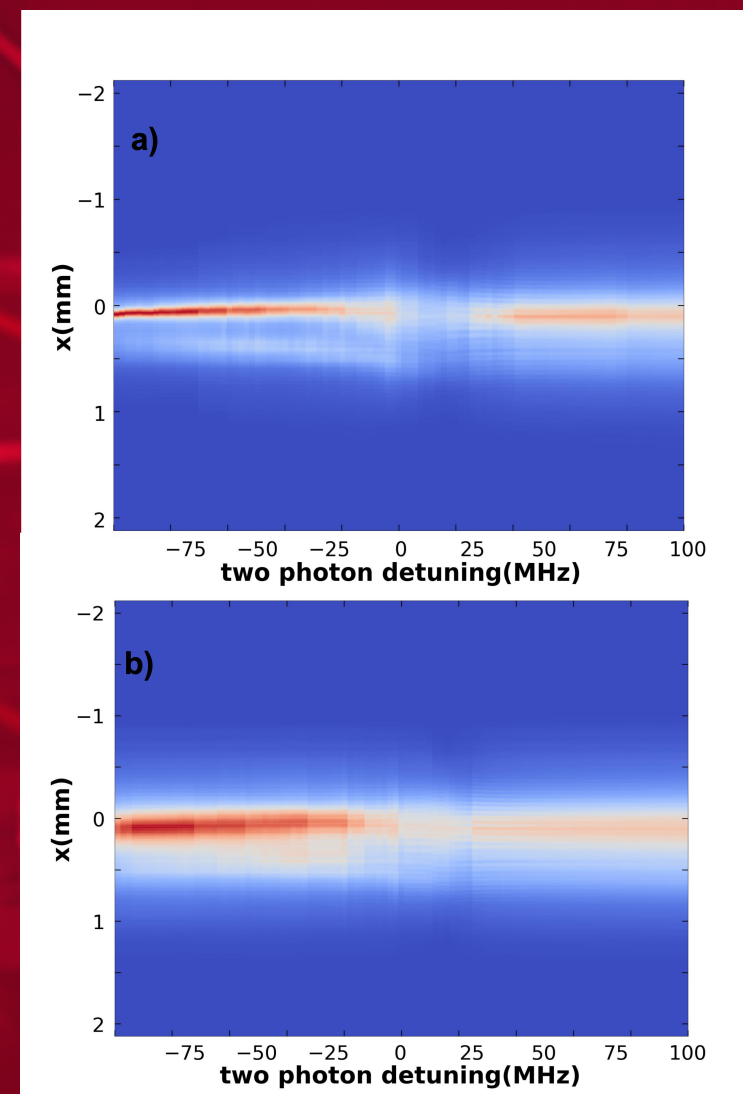
T= 120 °C

T= 100 °C

$\Delta_C = 1100 \text{ MHz}$



$\Delta_C = 1300 \text{ MHz}$



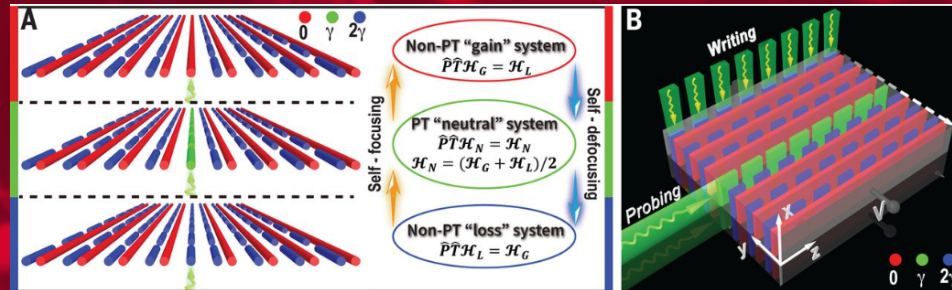
Zaključak

- Ukratko objašnjen postupak dobivanja diskretne difrakcije na optički induciranim rešetkama
- Ponašanje diskretne difrakcije ovisno o veličini rešetke i o fokusiranju probe u tamnu, odnosno svijetlu prugu
- Pojava solitona ovisno o snazi probe i frekventnom pomaku probe i pumpe
- Bogata podloga za istraživanje kompleksnih kvantnih i optičkih fenomena
- Sljedeći korak: 2D rešetka

Zaključak

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- Sljedeći korak: 2D rešetka

PT simetrija

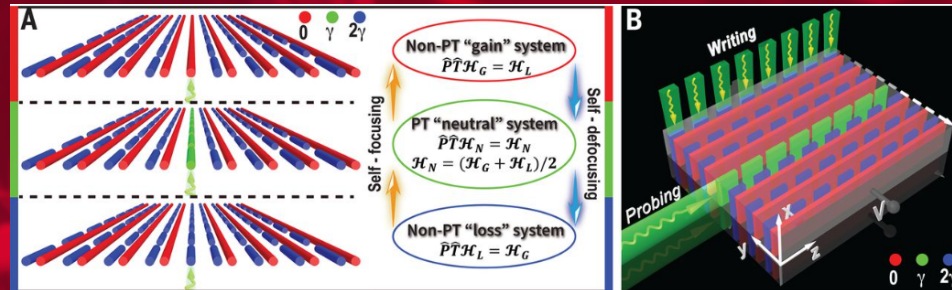


S. Xia *et al.*, Science 372, 6537
(2021)

Zaključak

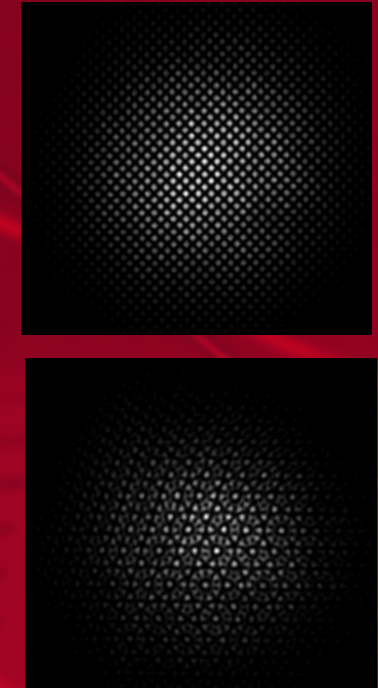
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- Sljedeći korak: 2D rešetka

PT simetrija



S. Xia *et al.*, Science 372, 6537
(2021)

2D rešetka



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CENTRE FOR ADVANCED LASER TECHNIQUES

Hvala na pažnji!

Projekt je sufinanciran u okviru OP Konkurentnost i kohezija, iz Europskog fonda za regionalni razvoj.

Dodatak

Optické Blochove rovnice

$$\frac{\partial \rho_{11}}{\partial t} = \frac{-i\mu_{13}E_p}{\hbar}(\sigma_{13} - \sigma_{31}) + \Gamma_{13}\rho_{33},$$

$$\frac{\partial \rho_{22}}{\partial t} = \frac{-i\mu_{23}E_C}{\hbar}(\sigma_{23} - \sigma_{32}) + \Gamma_{23}\rho_{33},$$

$$\frac{\partial \rho_{33}}{\partial t} = \frac{i\mu_{13}E_p}{\hbar}(\sigma_{13} - \sigma_{31}) + \frac{i\mu_{23}E_C}{\hbar}(\sigma_{23} - \sigma_{32}) - (\Gamma_{13} + \Gamma_{23})\rho_{33},$$

$$\frac{\partial \sigma_{12}}{\partial t} = \frac{-i\mu_{23}E_C}{\hbar}\sigma_{13} + \frac{i\mu_{13}E_p}{\hbar}\sigma_{32} + [i(\Delta c - \Delta p) - \gamma_{12}]\sigma_{12},$$

$$\frac{\partial \sigma_{13}}{\partial t} = \frac{i\mu_{13}E_p}{\hbar}(\rho_{33} - \rho_{11}) - \frac{i\mu_{23}E_C}{\hbar}\sigma_{12} - \left(i\Delta p + \gamma_{13} + \frac{\Gamma_{13}}{2} + \frac{\Gamma_{23}}{2}\right)\sigma_{13},$$

$$\frac{\partial \sigma_{23}}{\partial t} = \frac{i\mu_{23}E_C}{\hbar}(\rho_{33} - \rho_{22}) - \frac{i\mu_{13}E_p}{\hbar}\sigma_{21} - \left(i\Delta c + \gamma_{23} + \frac{\Gamma_{13}}{2} + \frac{\Gamma_{23}}{2}\right)\sigma_{23},$$