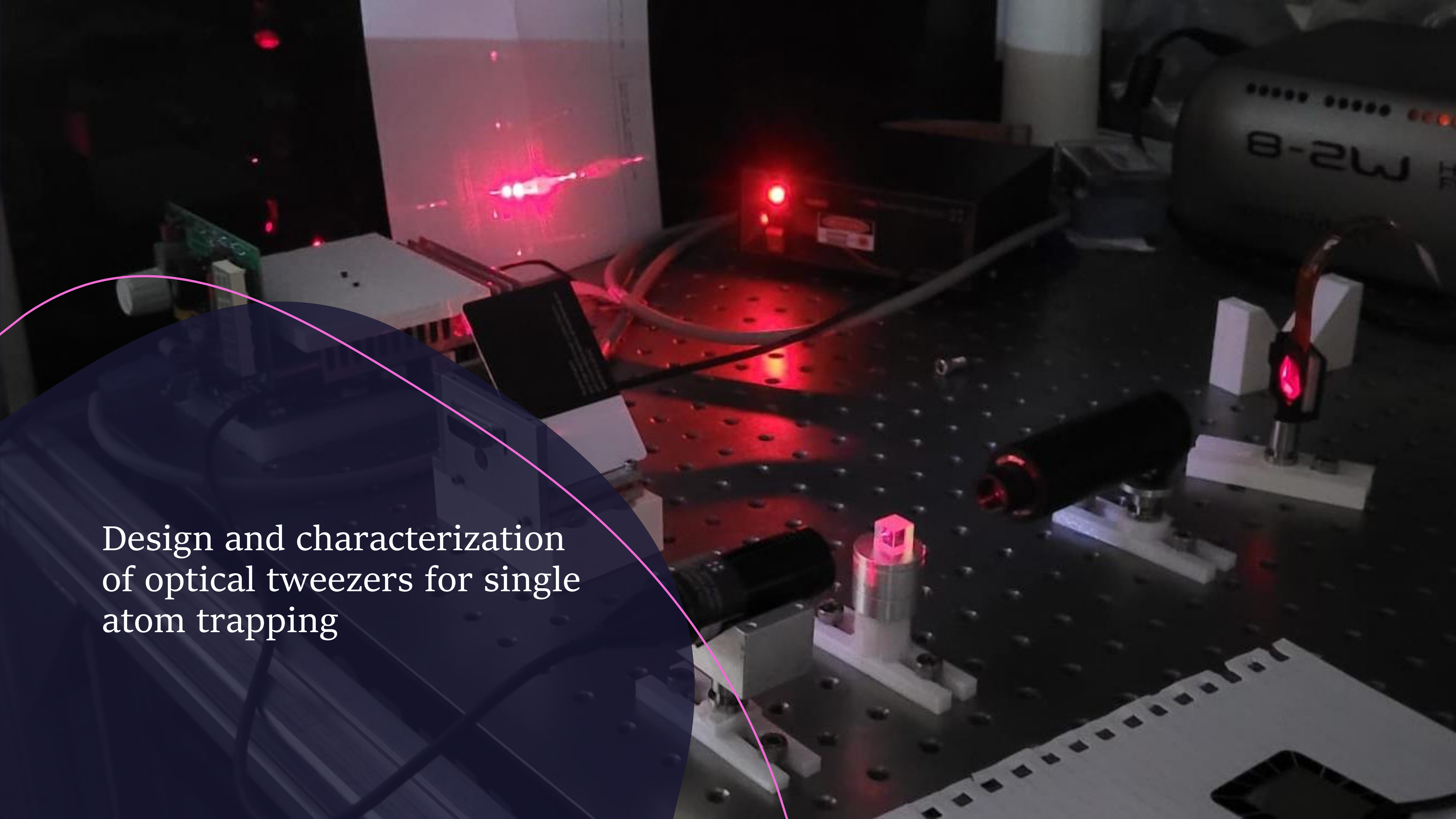
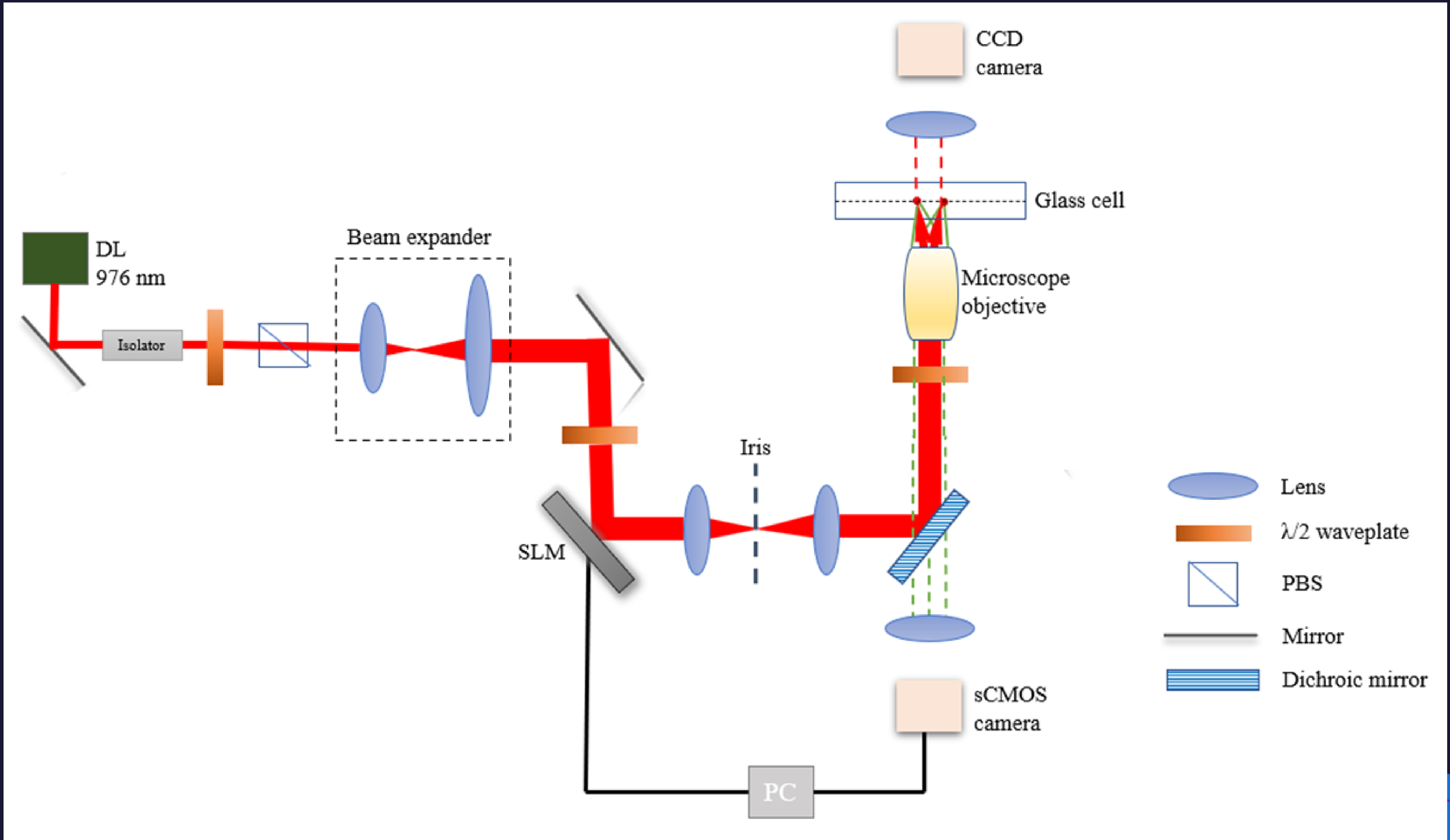
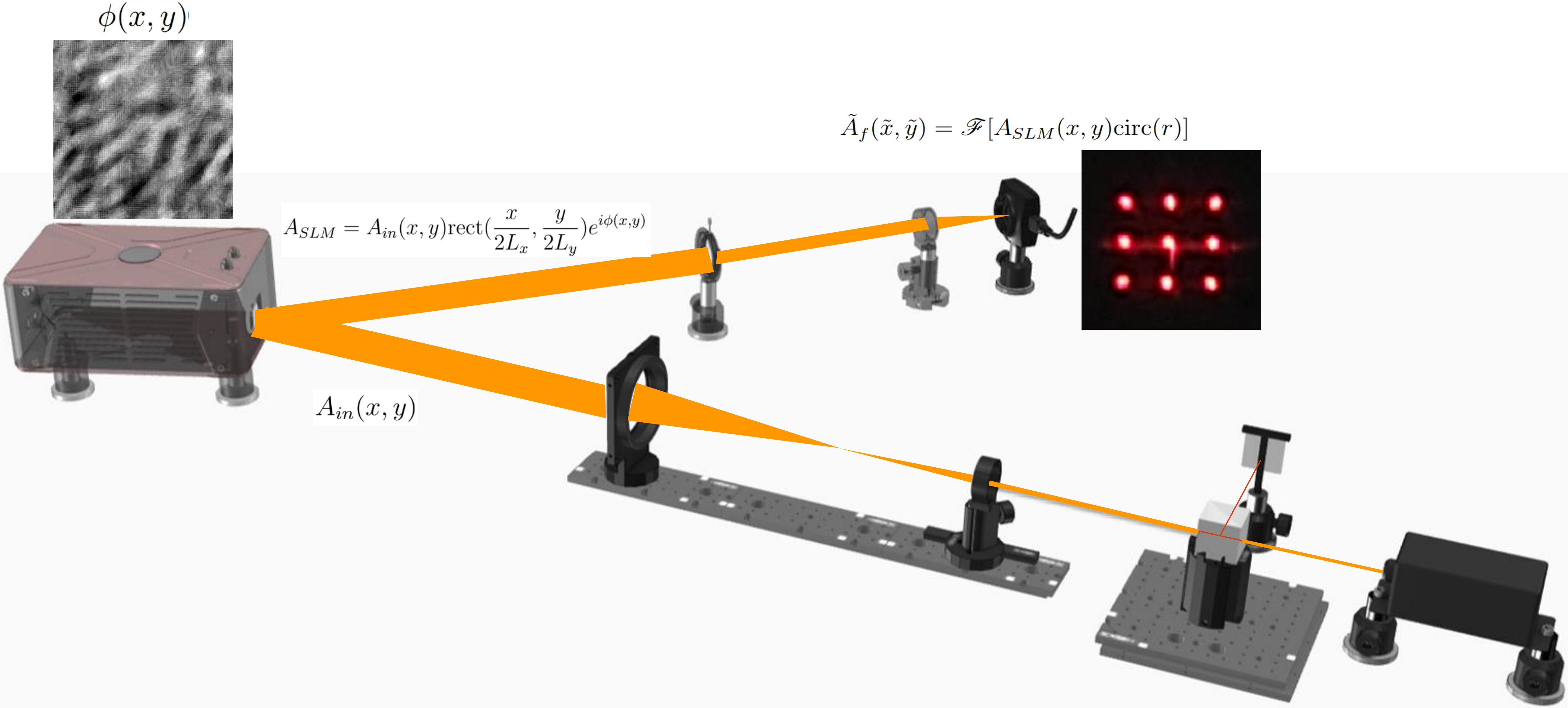


Design and characterization of optical tweezers for single atom trapping

Optical Setup



Generation of Optical Tweezers



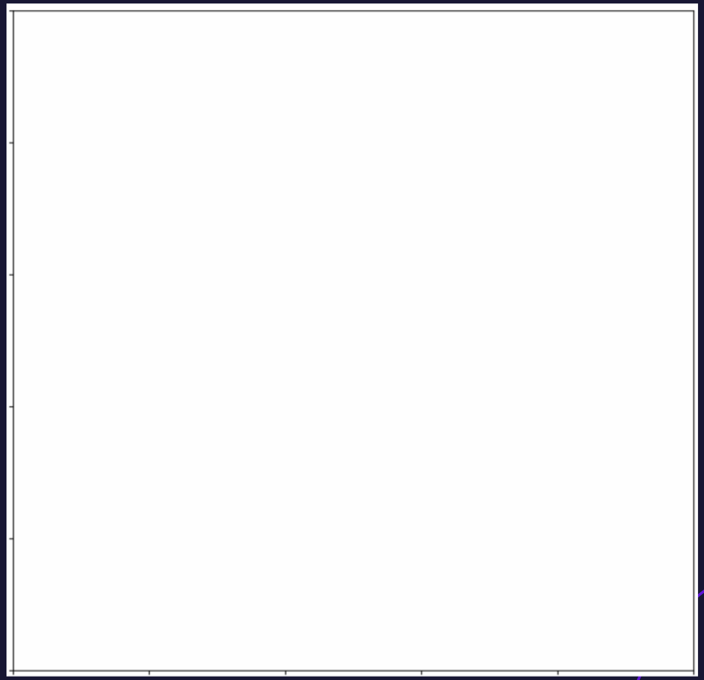
Defect free atom array

Why?

- For quantum computing, we need continuous array of atoms

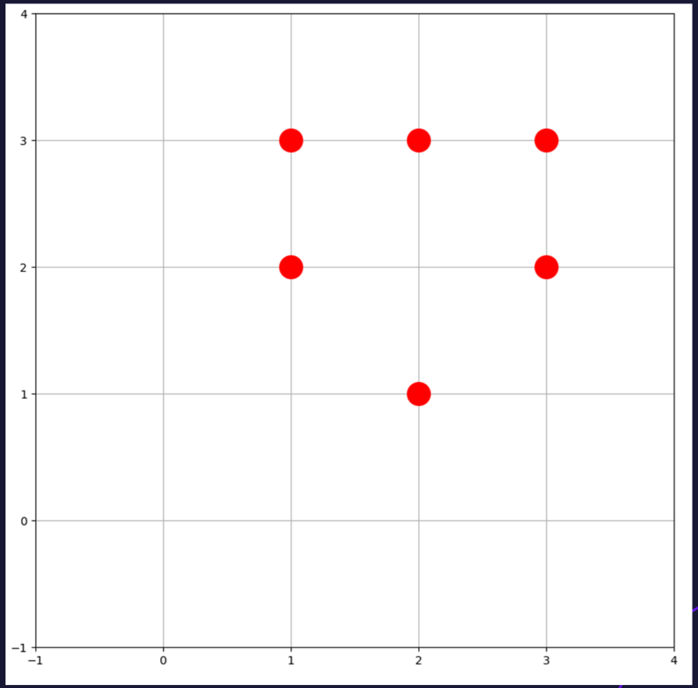
Why we get array with defects?

- Probability of atom getting trapped at each sites is 0.5
- probability for trapping N atoms is $(0.5)^N$, e.g. trapping 9 atoms it is around 0.002



Defect free atom array

- **How to increases probability?**
  - One approach is to design a system to capture atom >2N
  - Afterwards, fill vacant sites from nearby reservoir atoms



Defect free atom array

- **Why it has higher probability?**
  - Probability is equivalent to P(N|M), where N is #atoms we want out of M traps

$$P(N|M) = \left(\frac{1}{2}\right)^{M} \sum_{n=N}^{M} \binom{M}{n}$$

For N = 9 and M = 25, probability of obtaining defect free atom is about 0.9

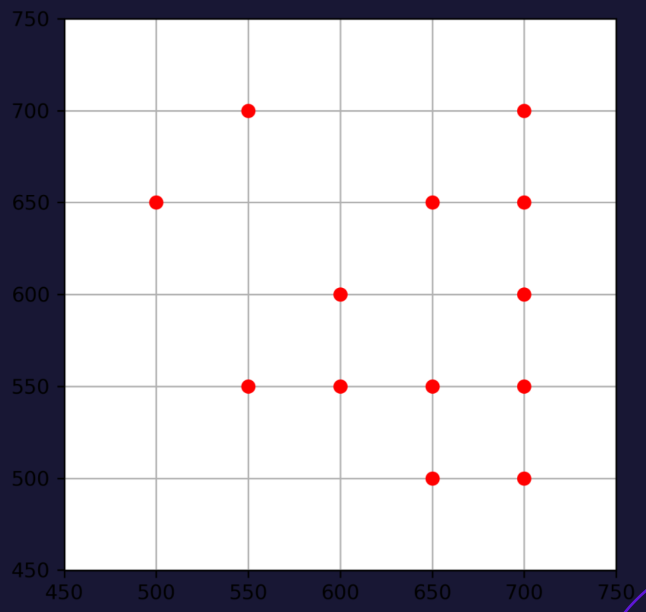
Defect free atom array

- **How will we approach?**

1. Determine the location of trapped atoms
2. Identify the target positions of atoms
3. Matching between reservoir atoms and voids
4. Path Planning
5. Generation of phase mask and movement of tweezers

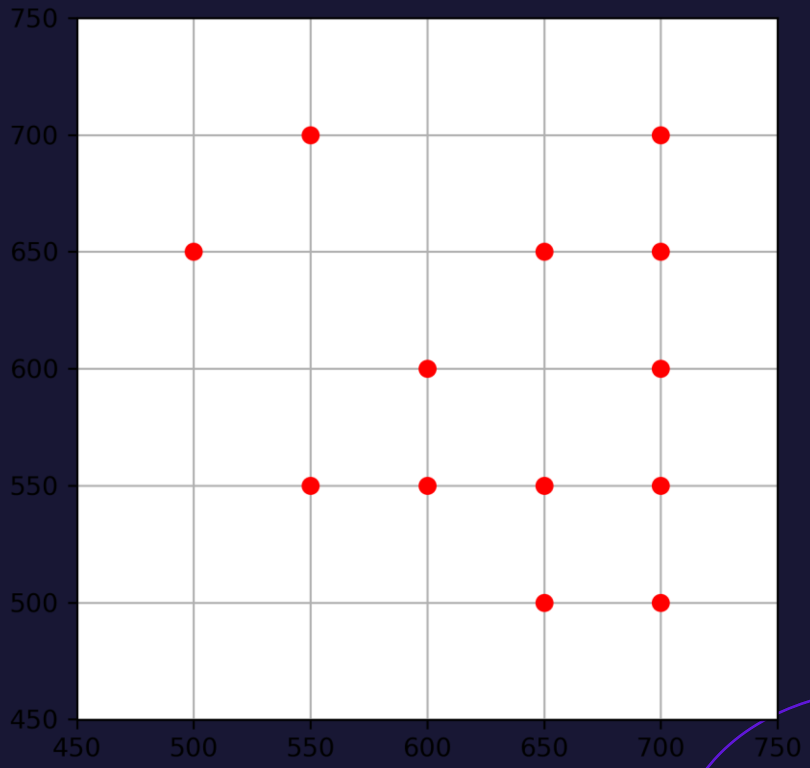
Defect free atom array

- **Determination of location of trapped atoms**
  - In original experiment, image of fluorescence of the atom captured will determine location
  - For now, trapped atom configuration is generated randomly
    - Known dimensions n
    - Probability of each site = 0.5
    - Pre defined spacing between sites



Defect free atom array

- **Identification of target positions of atoms**
  - Optimal position of centre target array position obtained through Centre of Mass (COM) strategy



Defect free atom array

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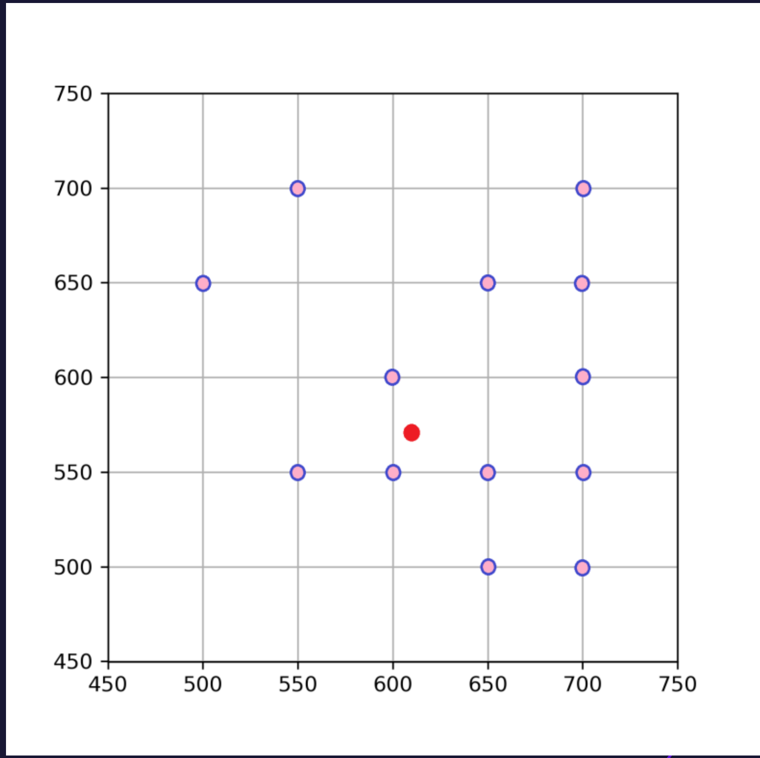

Defect free atom array

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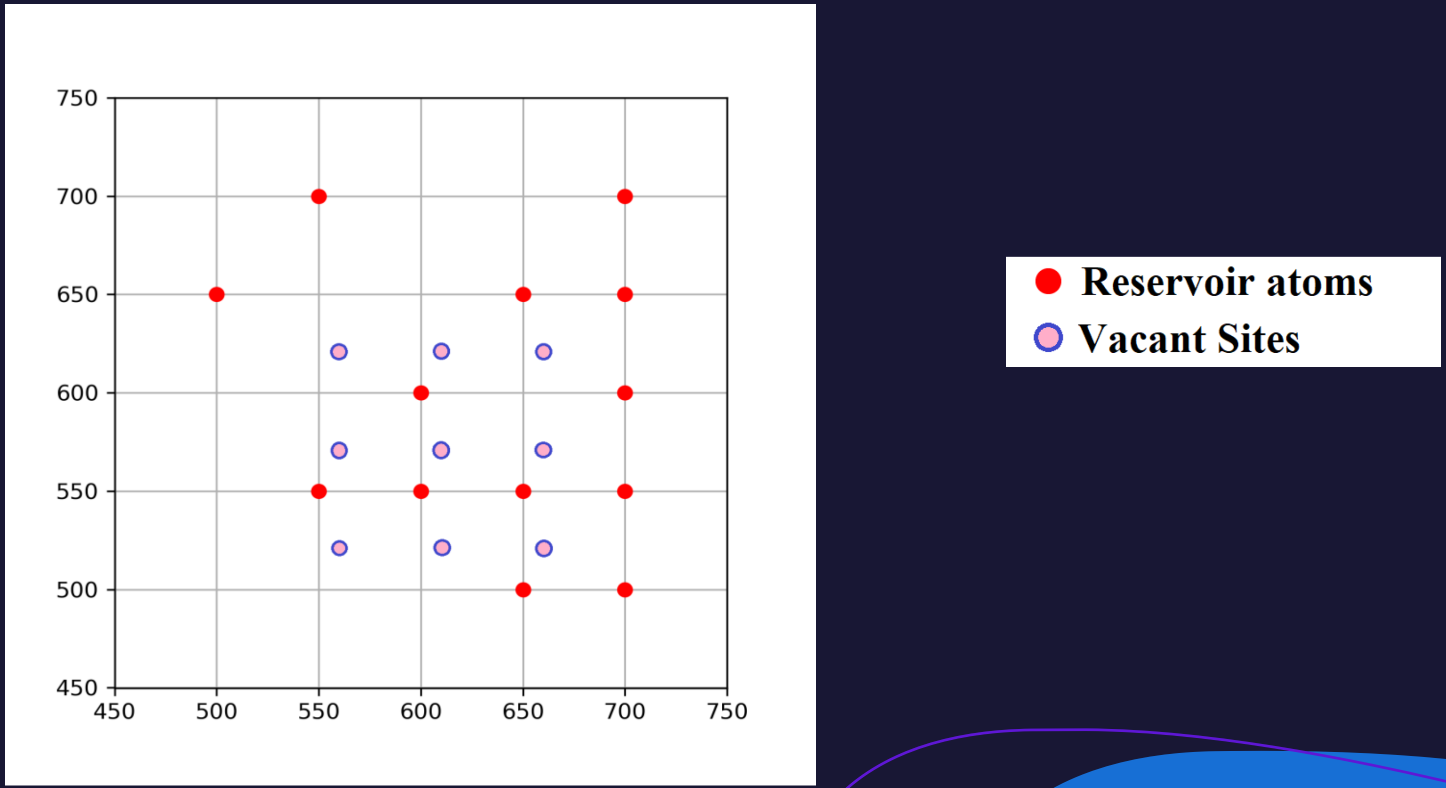
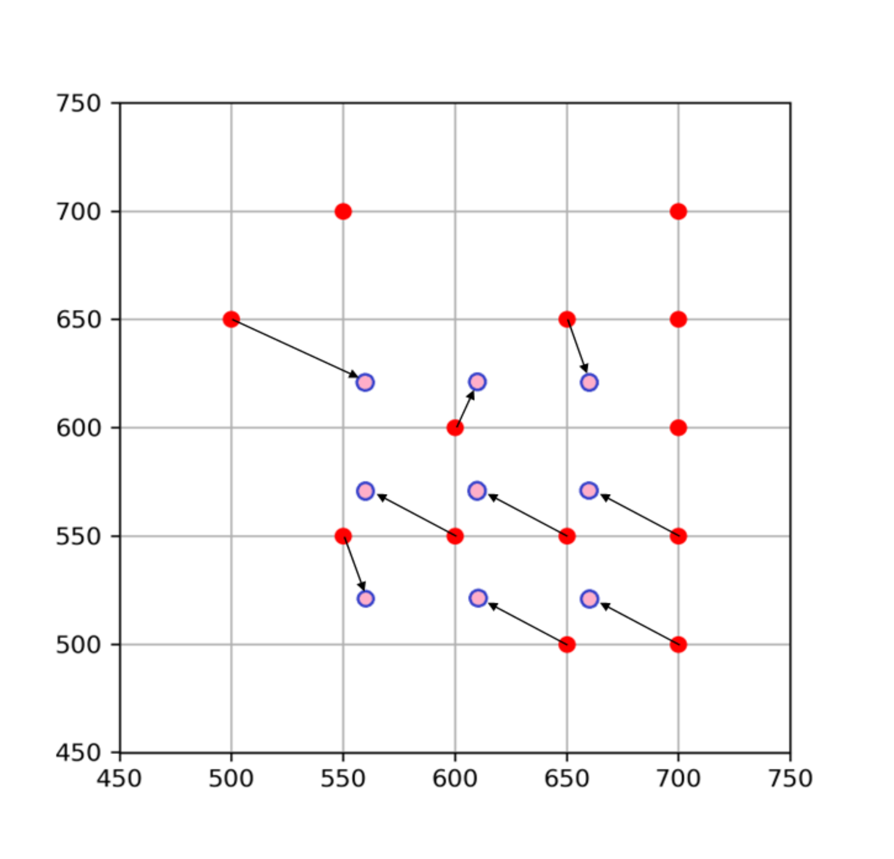
  - Optimal position of centre target array position obtained through Centre of Mass (COM) strategy



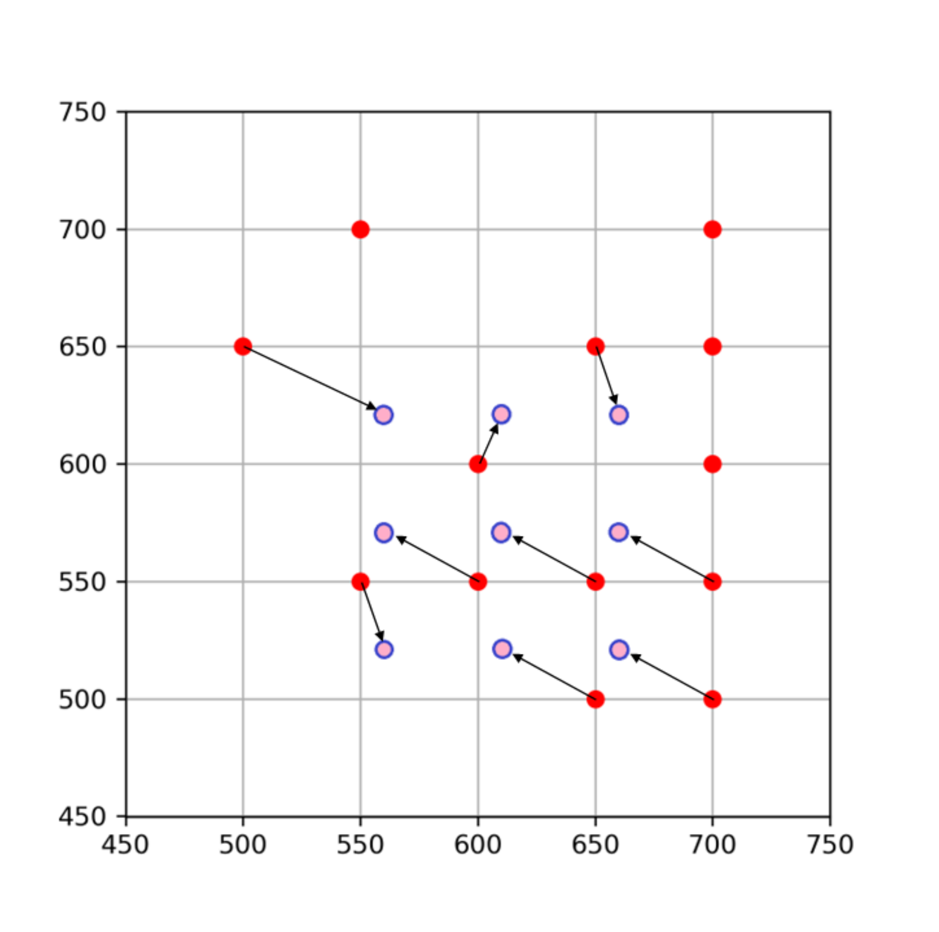
Defect free atom array

- **Matching between void and reservoir atoms**
  - Matching can be done using
    - Brute Force (Time complexity: exponential)
    - Hopcroft – Karp Algorithm (Time complexity: polynomial)
    - Hungarian Algorithm (Time complexity: polynomial)
  - Hopcroft – Karp Algorithm gives matching without any constraint
  - Hungarian Algorithm gives matching by minimizing the constraint
  - Distance between void sites and reservoir is used as constraint



Defect free atom array

- **Obtaining Path**
  - Atom will be moved in straight line
  - Speed of movement of tweezers depends on:
    - # frame
    - Frame rate



Defect free atom array

- Movement of tweezers
  - Generation of phase mask for each frame
  - Projecting each phase mask on SLM with desired frame rate