3. Experiments

3.1 Optical image addition and subtraction

A. Construct 4f optical path

1) Refer to Figure 1, place the laser head, beam expander (f=4.5 mm) and collimation lens (f=225 mm) on the rail;
2) Adjust laser, beam expander and collimation lens to get collimated beam parallel to the rail and propagating along the rail central line;
3) Place the object (the plate with two separated slits, one vertical and one horizontal), two FT lenses (f=150 mm), and the white screen behind the collimation lens; adjust their centers to be coincided with the beam center, and the distances between these components as shown in Figure 1,

   Note: (1) in order to adjust the object in horizontal direction, the carrier of the object should be x-adjustable. (2) Place the laser tube and the white screen farthest away on the rail. In case the rail is not long enough to properly arrange all components on it, move the white screen outside the rail on the extension line of the rail.
4) Now, the 4f optical path is constructed.

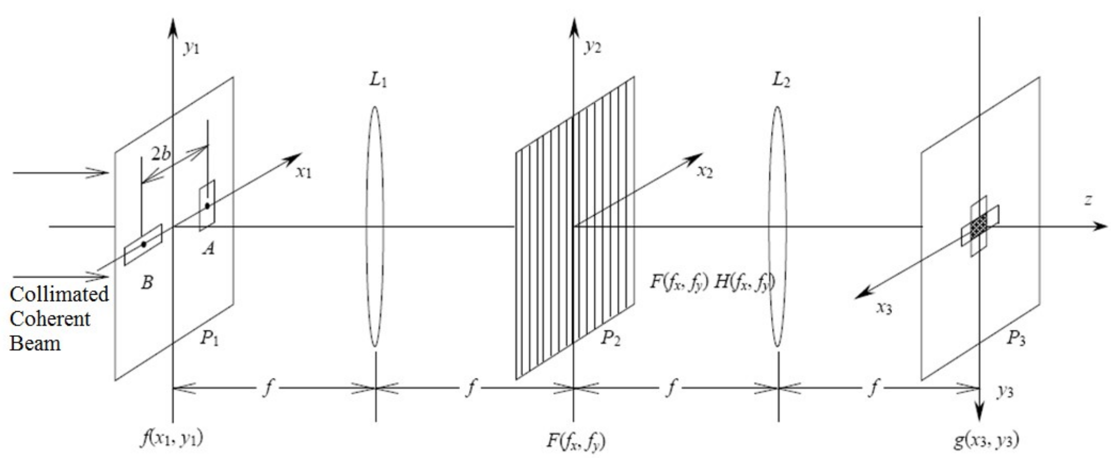

Figure 5 Schematic of the experimental optical path

B. Grating filtering

1) Refer to Figure 5, place the 1-D grating (100 *l/mm*) on the back focal plane of Lens L_1 (i.e. the middle plane between the two FT lenses, or plane P_2), also the carrier of the grating should be x-adjustable,

2) Observe image on the white screen (plane P_3); if the image is not clear, slightly adjust the positions of the object or/and the screen,

3) Shift the 1-D grating horizontally (using x-translation of the carrier), observe the $+1^{st}$ order image of pattern A (the vertical slit) and the -1^{st} image of pattern B (the horizontal slit) on the screen,

4) Carefully shift the 1-D grating, make the centers of the two images coincident. If not, try to finely shift the object horizontally.

C. Observe images addition and subtraction

Continuously and finely shift the 1-D grating in one direction, the results of $A+B$ and $A-B$ can be observed alternatively; as the bright overlapping area is observed for $A+B$ case while the dark overlapping area is for $A-B$ case as shown in Figure 6. If more than one bright or dark fringes are observed within the overlapping area, the grating needs to be moved slightly back and forth along the optical path around the spectral plane in order to get only one bright or dark fringe within the overlapping area, at this time, the addition or subtraction result is optimal.

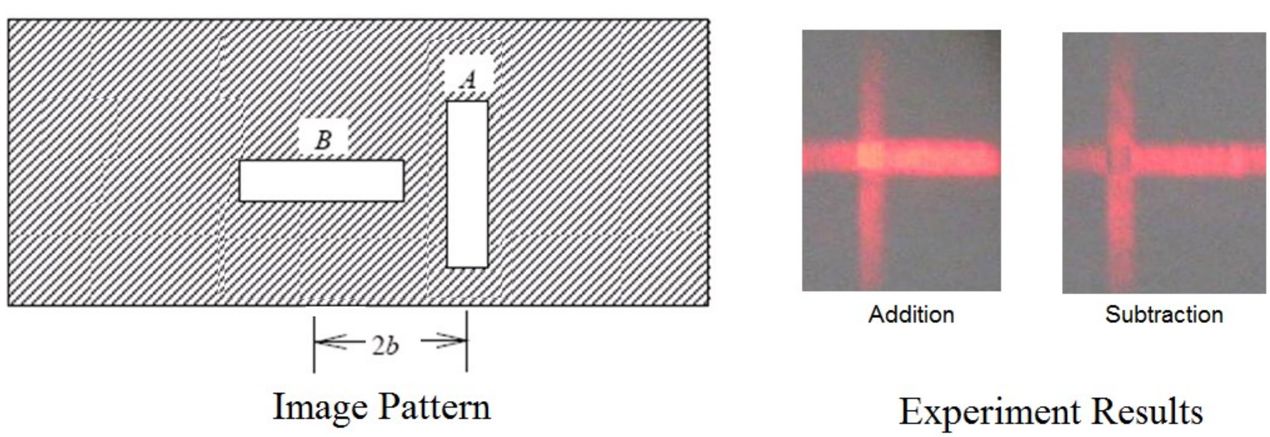

Figure 6 Schematic of image addition and subtraction operations

Note: If a complete dark overlapping area cannot be achieved for *A*-*B* case, it may be due to the following reasons:

a) The illumination on object plane for *A* and *B* are not even;

b) The calculation for f_0 and *b* is not correct, causing non-overlapping of their centers;

c) Optical path is not properly aligned.

3.2 Optical Image Differentiation

1) Refer to Figure 1, follow the same procedure to construct 4f optical path as described above, except that the object plate is replaced with the plate with a lying down “T” pattern and the 1-D grating is replaced with a composite grating,

2) Shift the composite grating horizontally while observing image changes on the white screen,

3) Carefully adjust the position or fringe direction of the composite grating to achieve optimal differentiation result (see Figure 7 below).

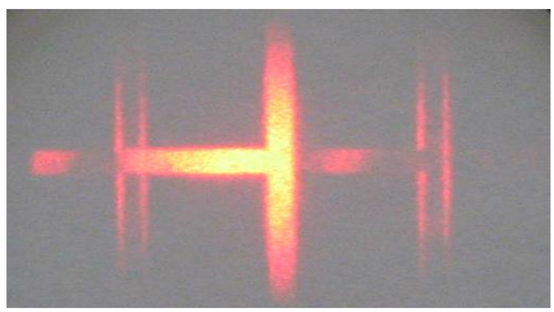

Figure 7 Experiment result of 1-D image differentiation