4B11 Photonic Systems

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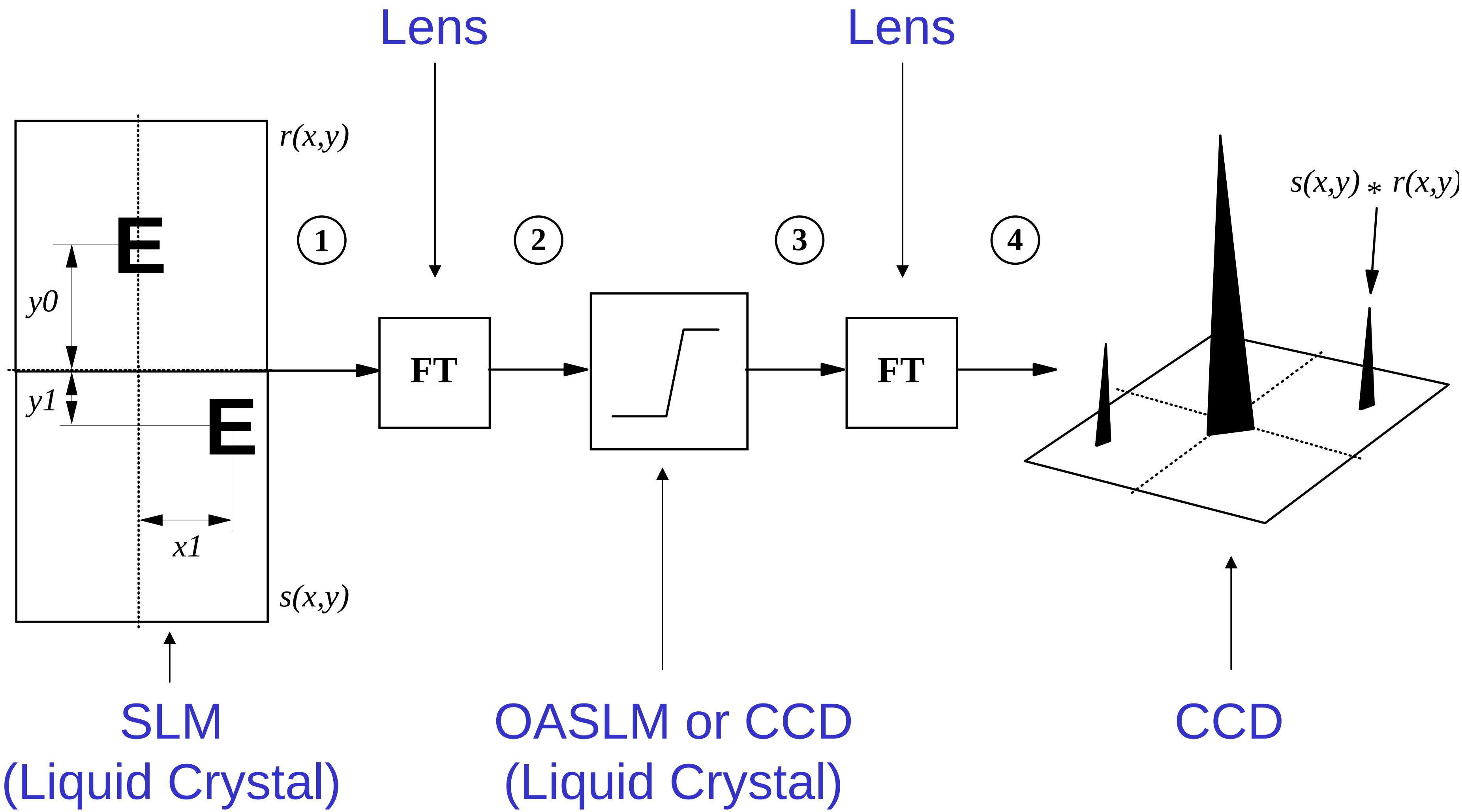
The 1/f JTC


Lens
Lens
r(x,y)
E
y0
y1
E
x1
s(x,y)
1
2
3
4
FT
FT
s(x,y) * r(x,y)
SLM
(Liquid Crystal)
OASLM or CCD
(Liquid Crystal)
CCD

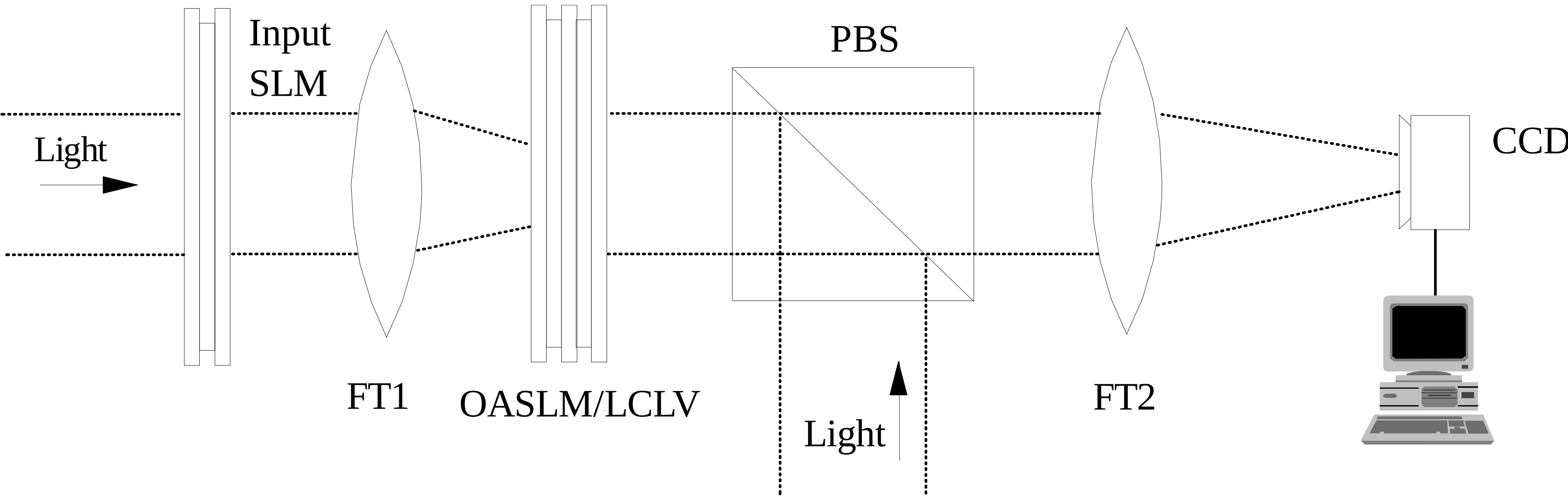
The JTC works on the basis of a non-linearity working on the spectrum of the input objects to create the product of the two Fourier transforms.

This was modelled as a square law detector, but this gives undesirable broad peaks.

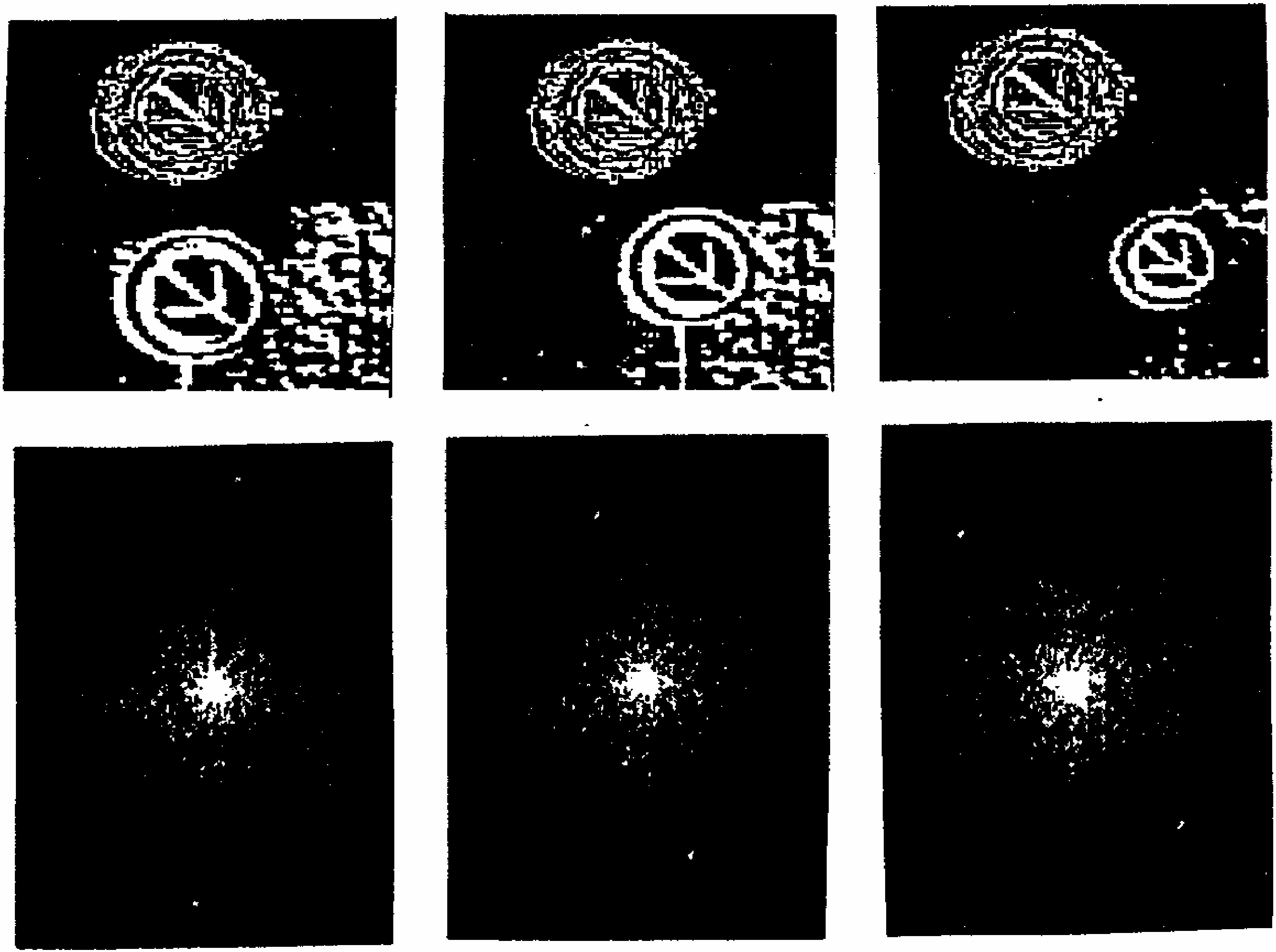
A much better correlation peak is obtained when the degree of non-linearity is increased as high as possible.

A simple square root function on the spectrum gives good narrow peaks, but the best performance is when the spectrum is thresholded.

Hence the JTC was originally built using an optically addressed FLC SLM.

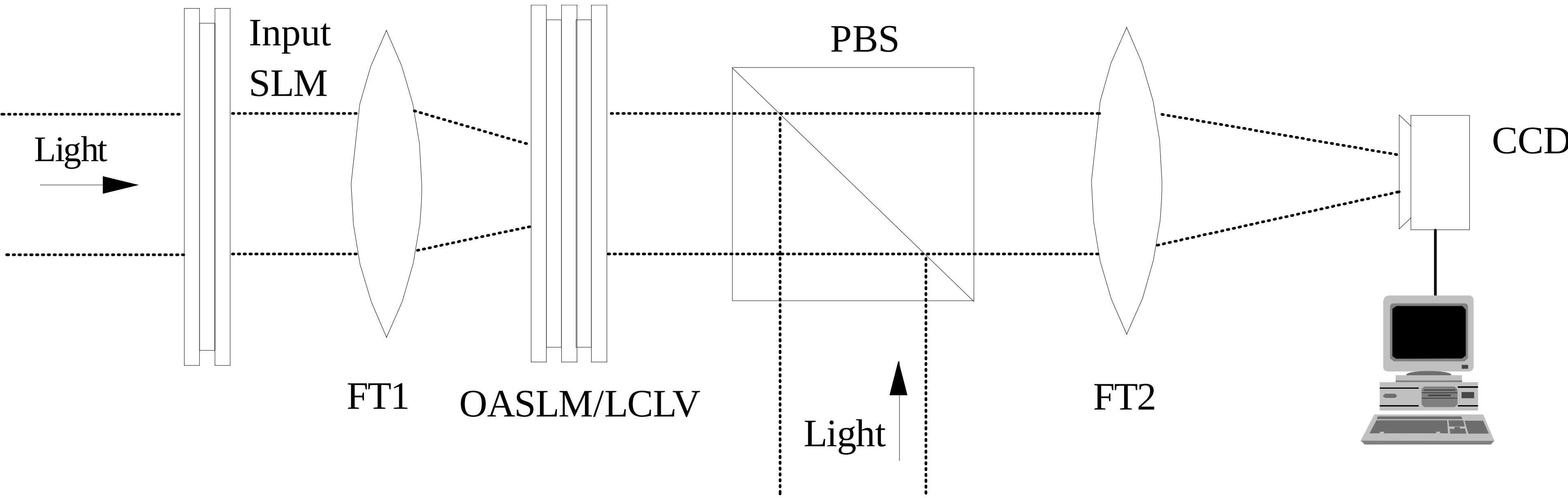


This gives great performance as the photoconductor of the OASLM acts at a square law detector and the FLC (in surface stabilised mode) acts as a binary thresholding function.



The JTC was too big and bulky as it required two lasers and a lot of optical components.

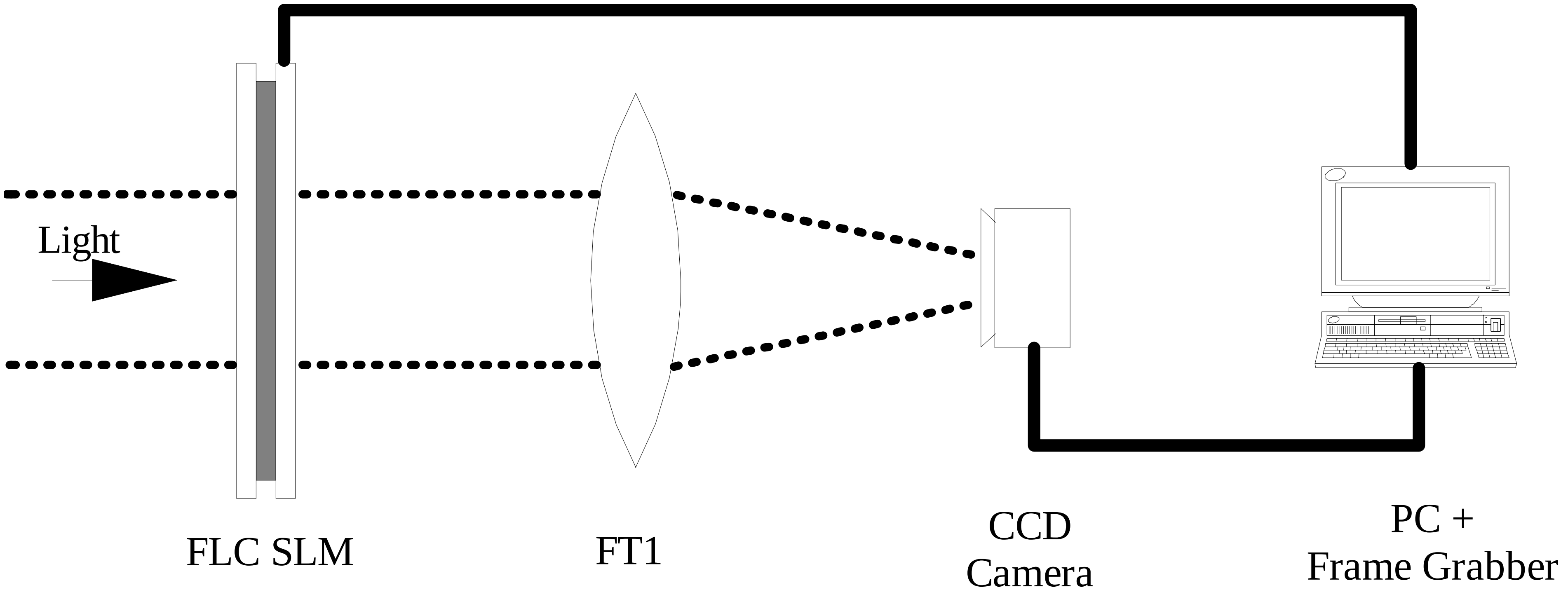
A better layout is to exploit the symmetry about the OALSM or non-linearity.



Input
SLM
PBS
Light
CCD
FT1
OASLM/LCLV
FT2
Light

If the optical system is split at this point, then the JTC just becomes two Fourier transforms and in fact can be done with a single laser, SLM and camera by doing two passes through the Fourier transform lens.

This is know as the 1/f JTC.


Light
FLC SLM
FT1
CCD
Camera
PC +
Frame Grabber

The input and reference images are displayed side by side on a FLC SLM as in a full JTC.

The SLM is illuminated by a collimated laser beam and the images are Fourier transformed by a single lens in its focal plane.

This spectrum is then imaged onto a CCD camera.

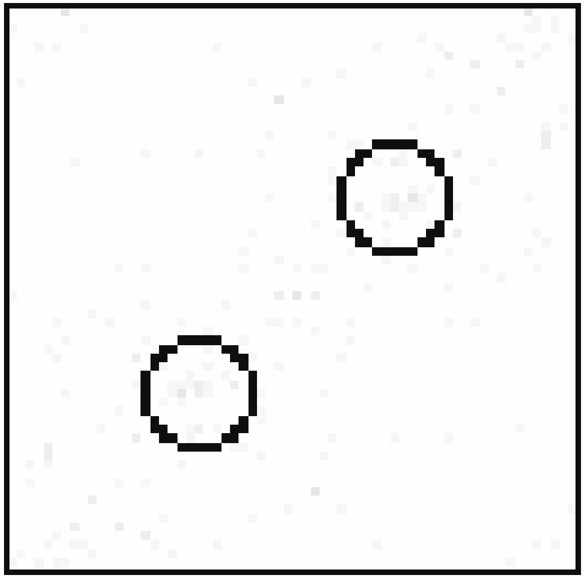
The spectrum is then non-linearly processed before being displayed onto the SLM again to form the correlation information.

The 1/f JTC is a two-pass system, using the same lens to perform the second Fourier transform.

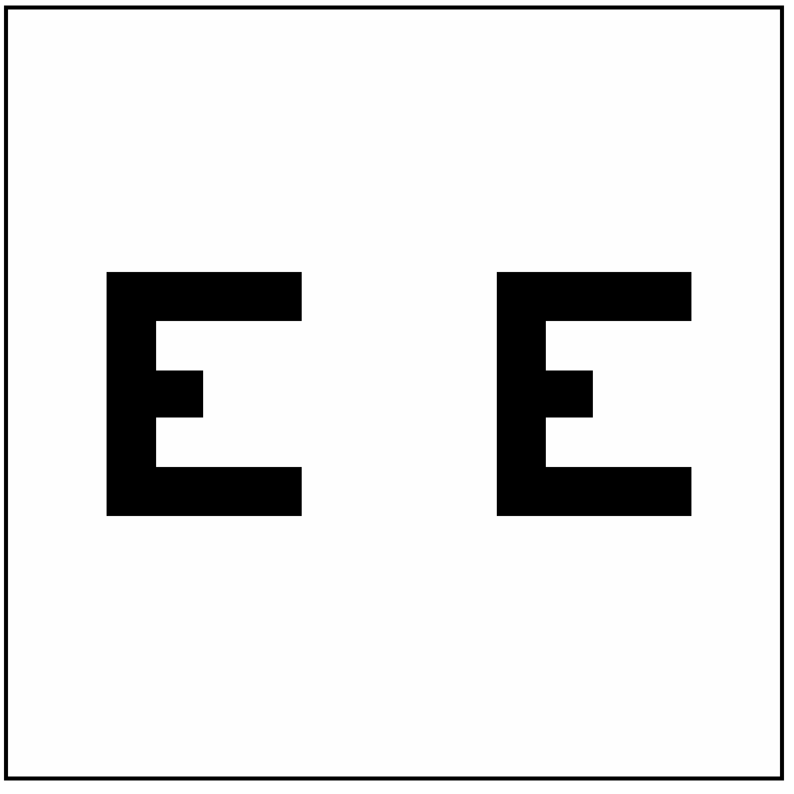
The quality of the correlation peaks and the zero order can be improved by non-linearly processing the spectrum that also suits the available FLC SLM technologies.

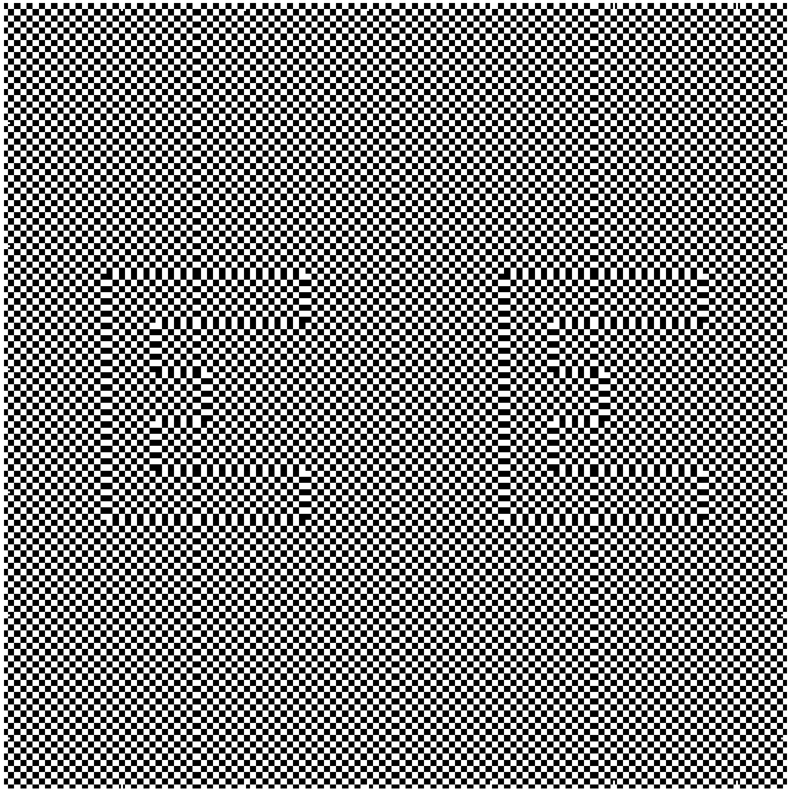
A binarised spectrum produces good sharp correlation peaks and reduced zero order.

Can we exploit the fact that a balanced CGH displayed in binary phase has no zero order?



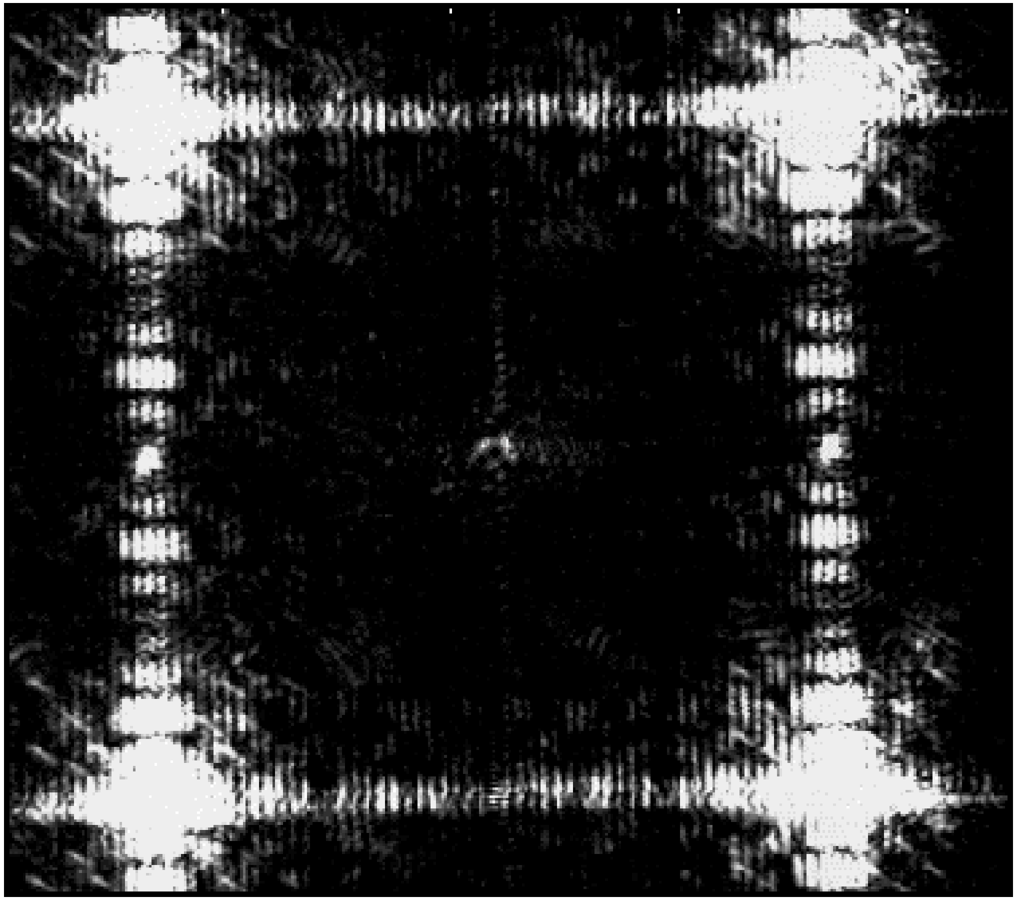
But what about the input images?





The multiplication of the input plane by the chequerboard ensures that the same number of -1 and +1 states are always present, independent of reference and input images.

Hence, there will be no zero order present in the spectrum of the input plane.



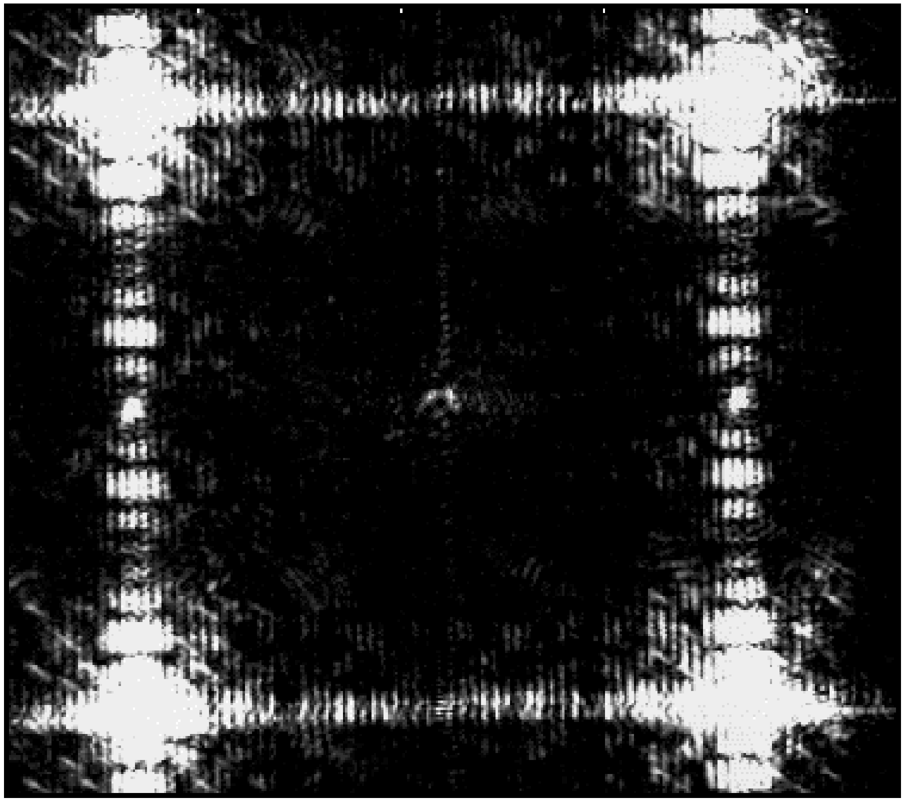
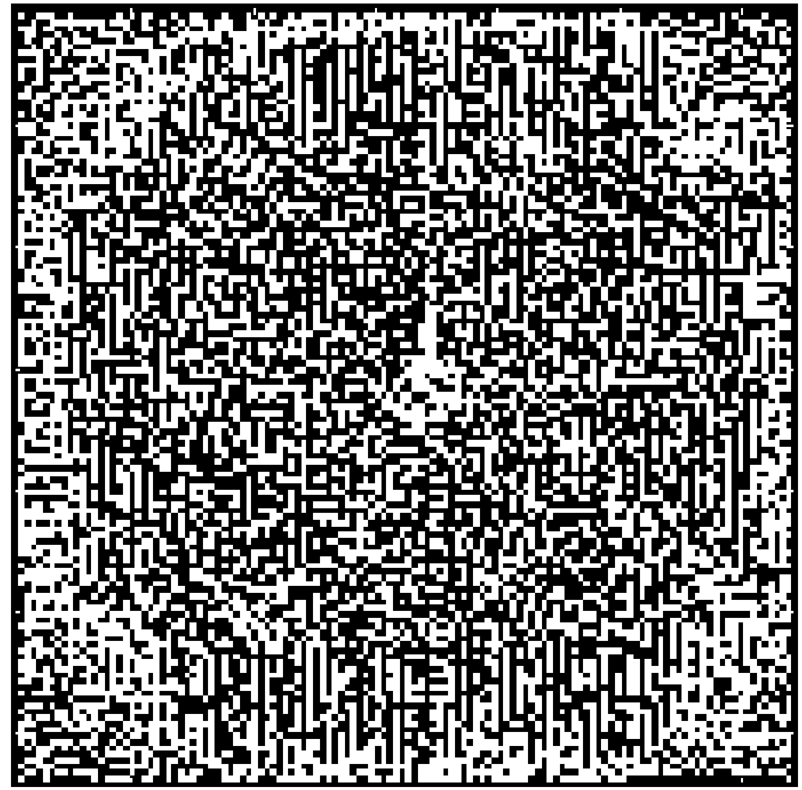
The first threshold technique was to use a basic median threshold filter on the spectrum, but this gave a very poor bitwise average after the threshold to binary phase.

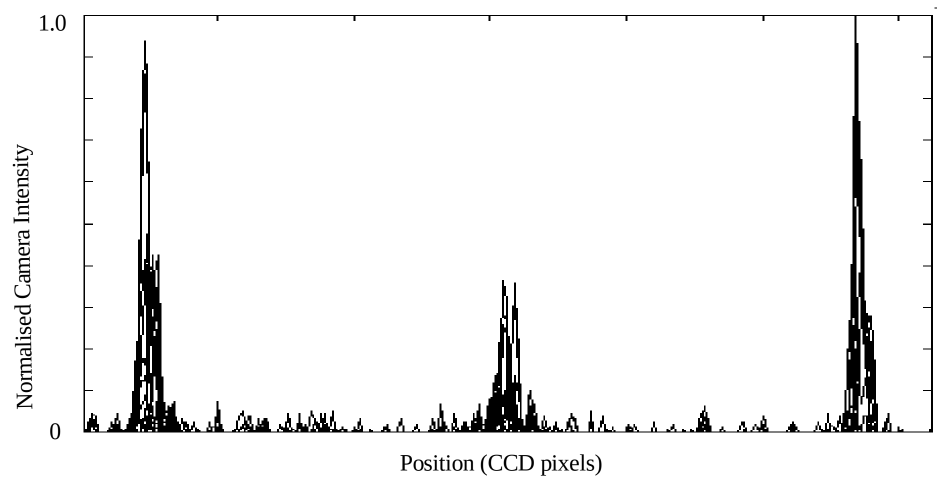
A 3x3 convolution binarisation scheme was also tried and gave reasonable results.

The success of this algorithm is due to fact that the 3x3 convolution is a form of edge enhancement, which enhances the spectrum and the noise in the dark areas.

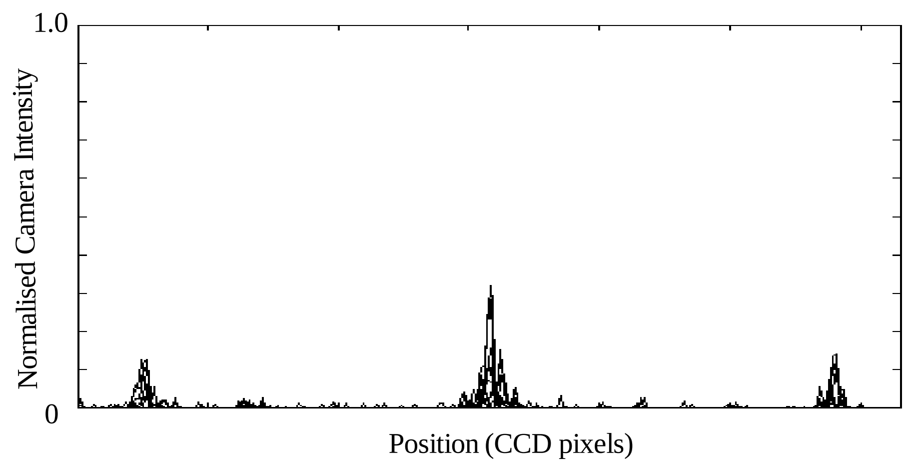
The best scheme was based on a nearest neighbour average comparison. The pixel to be binarised, P_{jk} is thresholded based on the average of its four nearest neighbours.

$$P_{j,k} = \begin{cases} +1 & \text{if} \quad P_{j,k} \geq \frac{1}{4}\left(P_{j-1,k} + P_{j+1,k} + P_{j,k-1} + P_{j,k+1}\right) \\ -1 & \text{Otherwise} \end{cases}$$

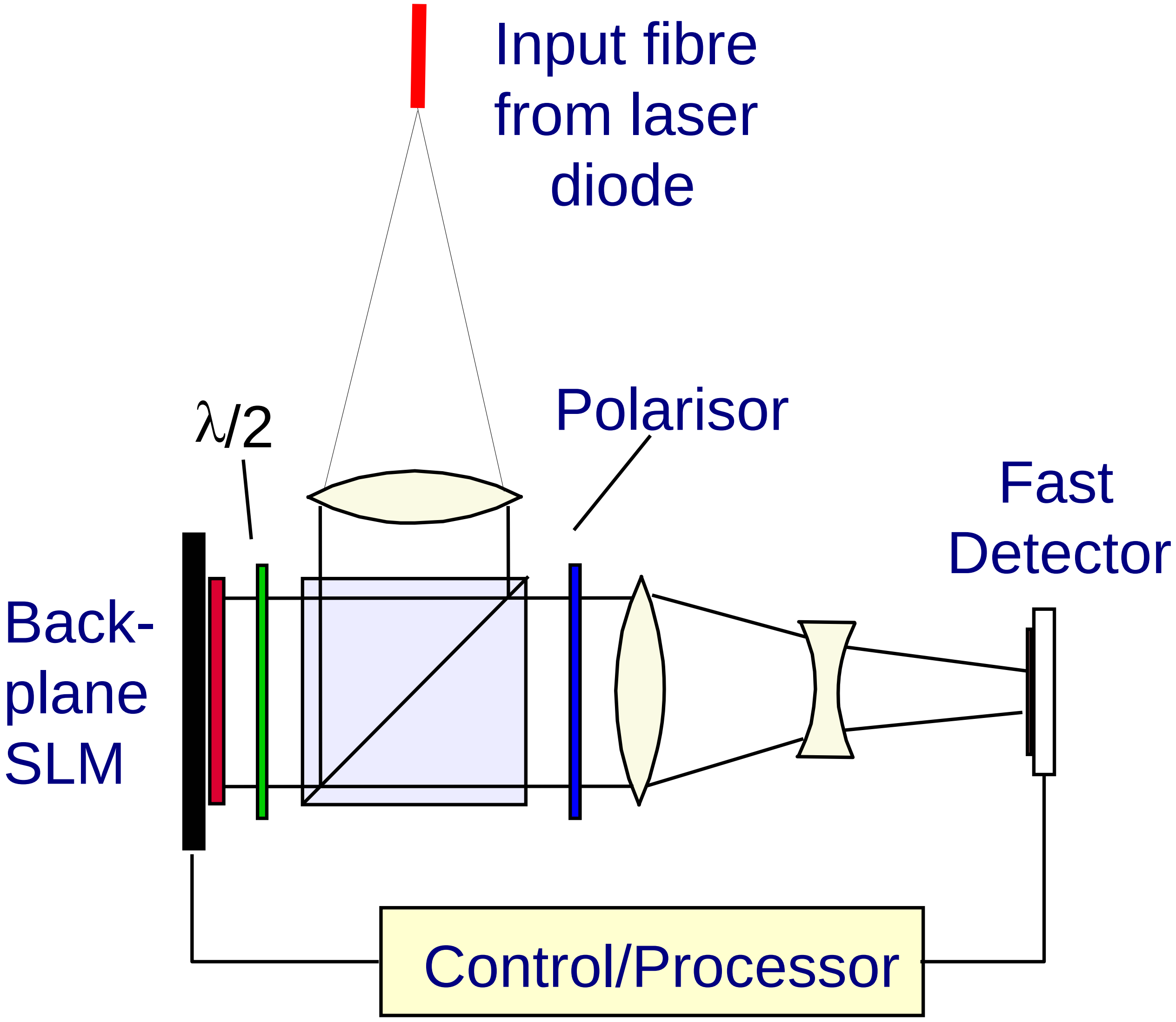

1.0
0
Normalised Camera Intensity
Position (CCD pixels)

E - E


1.0
0
Normalised Camera Intensity
Position (CCD pixels)

E - F

The 1/f system can be made into a powerful yet optically simple processor when it is implemented with a FLC LCOS SLM



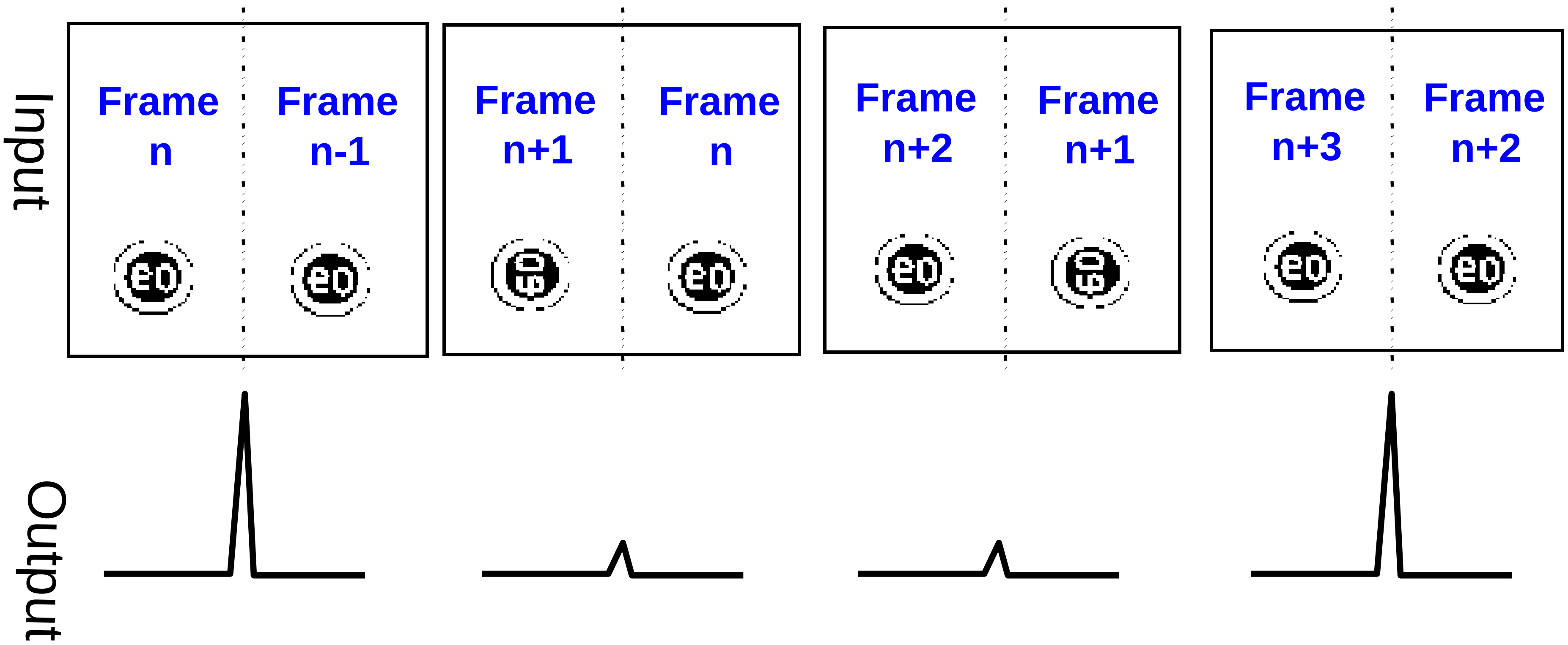

PULNIX

A very important observation is that the traditional 1/f JTC can be used as a 'recogniser' or comparator, where the reference image is unknown or unspecified.

Rather than having a pre-defined target or reference image, the input is made up from a sequence of frames from a video source.

We can compare sequential frames in a video stream of a production line.

In such an application, the current frame is the unknown and the previous frame is the 'reference'

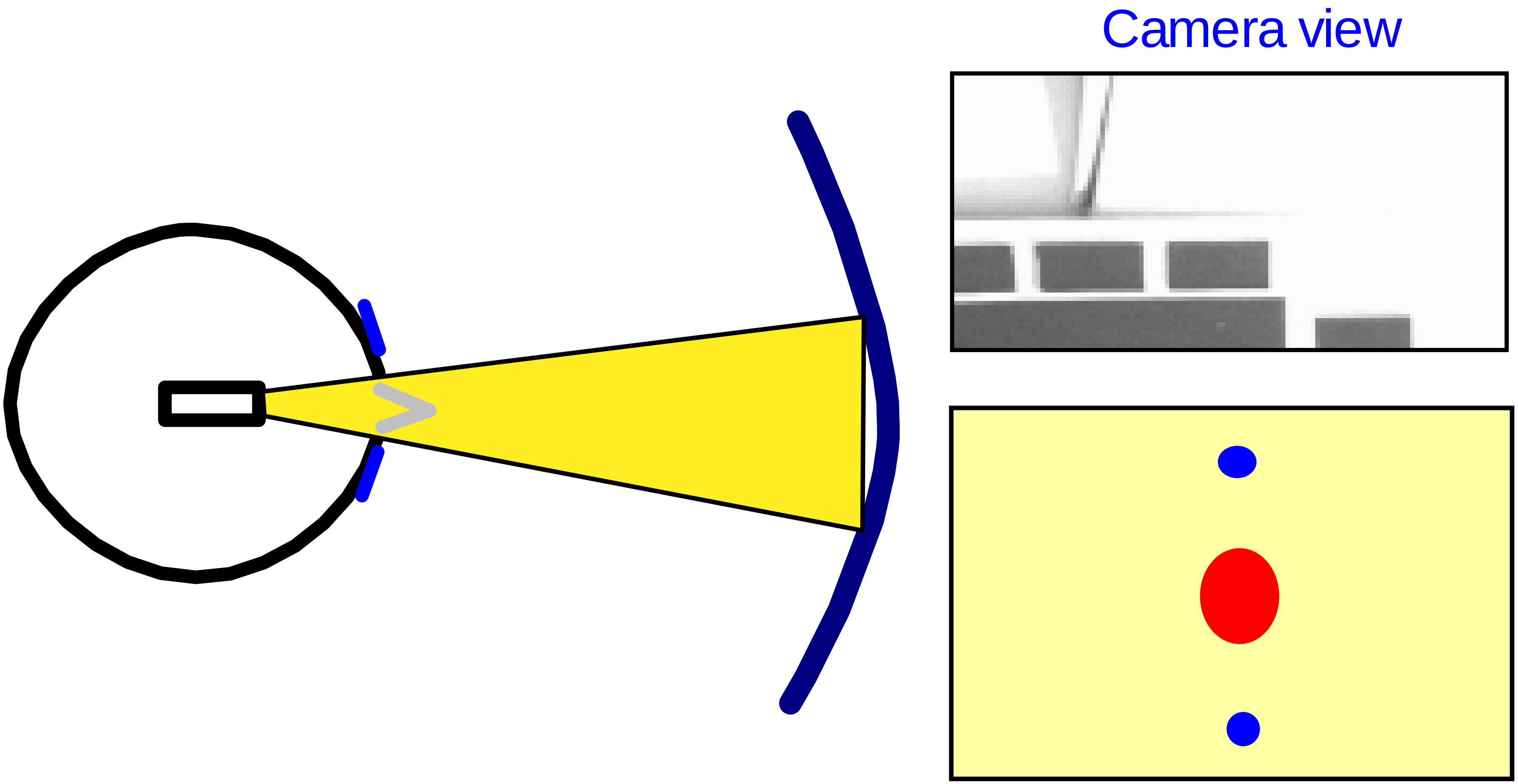

Input
Frame n
Frame n-1
Frame n+1
Frame n
Frame n+2
Frame n+1
Frame n+3
Frame n+2
Output

This frame by frame comparison system can be further extended to allow the correlator's inherent shift invariance to be exploited and a new dimension of object tracking added.

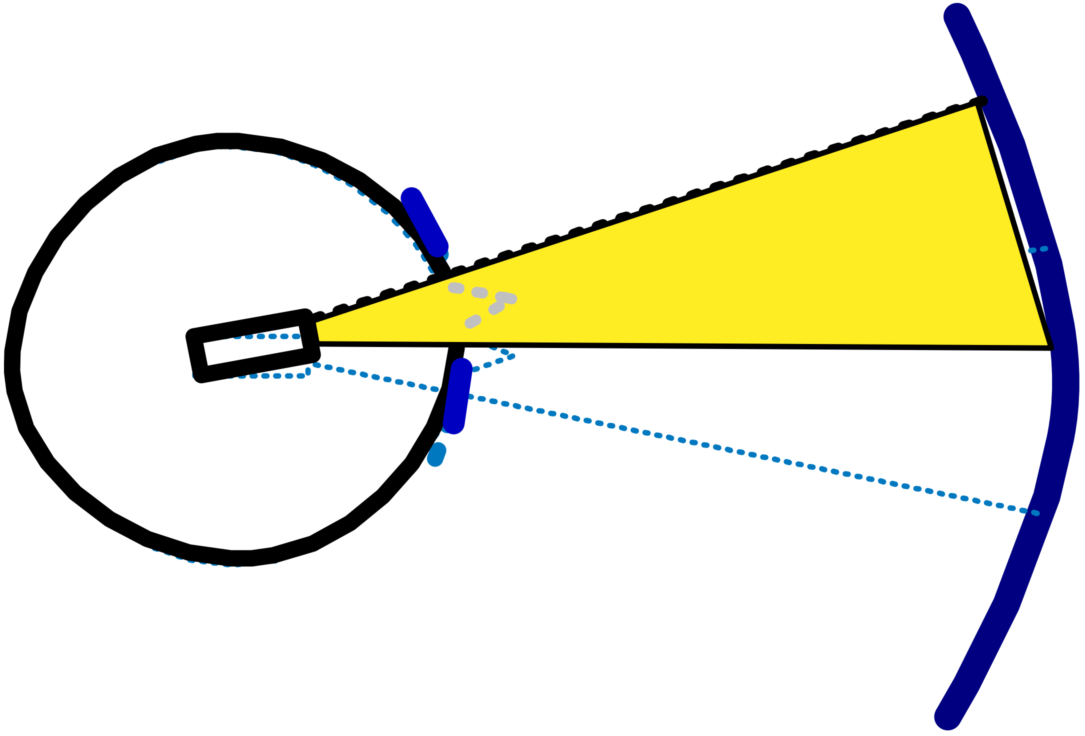
If we use the comparator to compare two identical frames, then there will be a strong correlation, which will be centred in the middle of the output plane.

If the object in frame *n*, shifts to the left, then the correlation between the two frames will also shift, and we can track the position of the object in frame *n* relative to its old position in frame *n-1*.

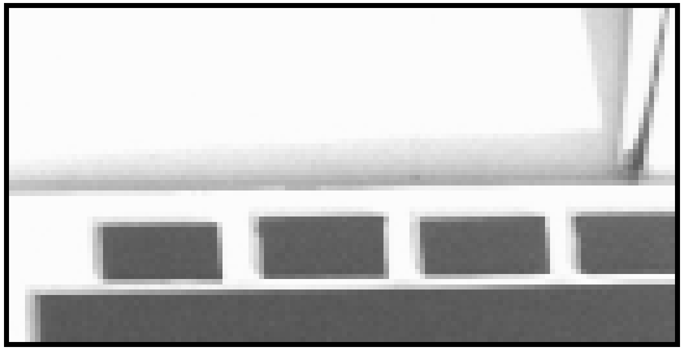
Furthermore we can keep tracking the relative position of the object from one frame to the next, as long at it stay within the frame and does not rotate or change scale.

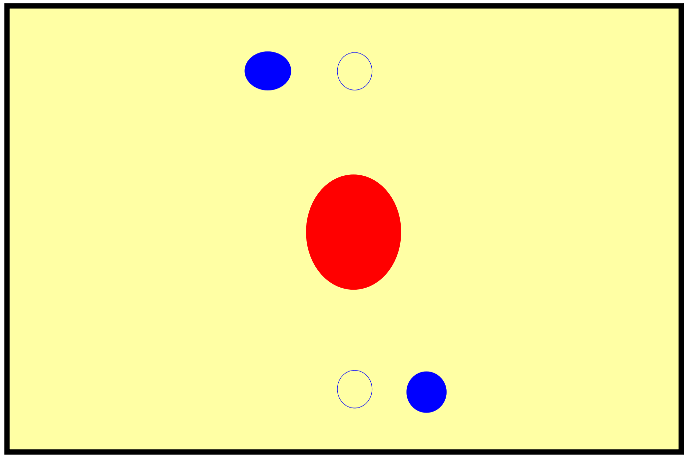


Compare view #1 with view #1

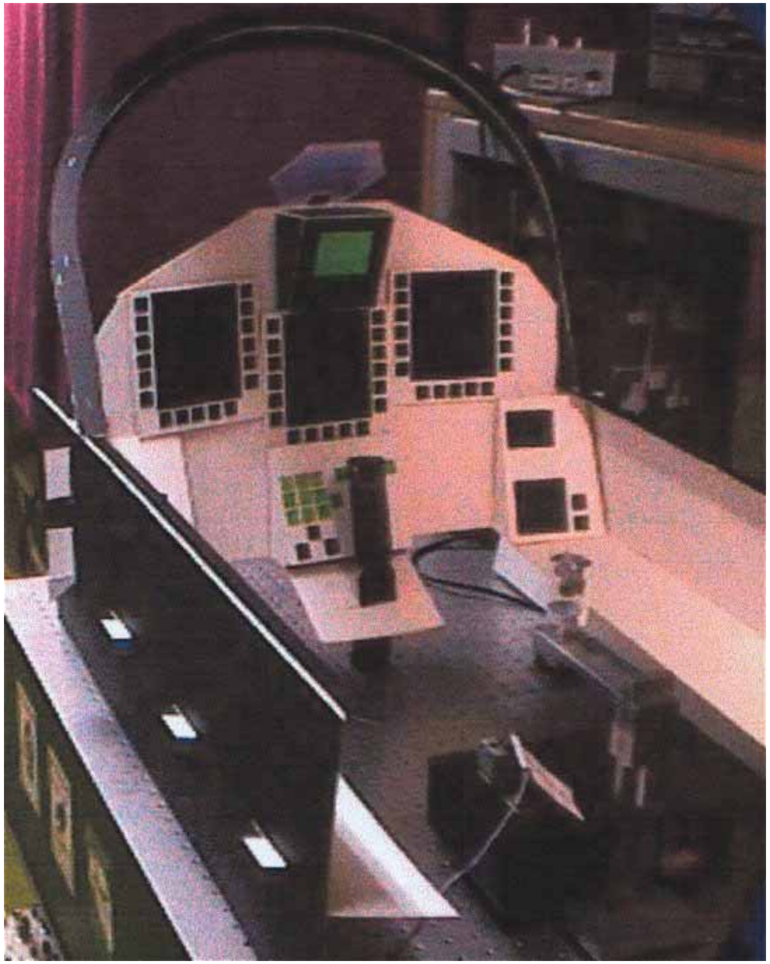


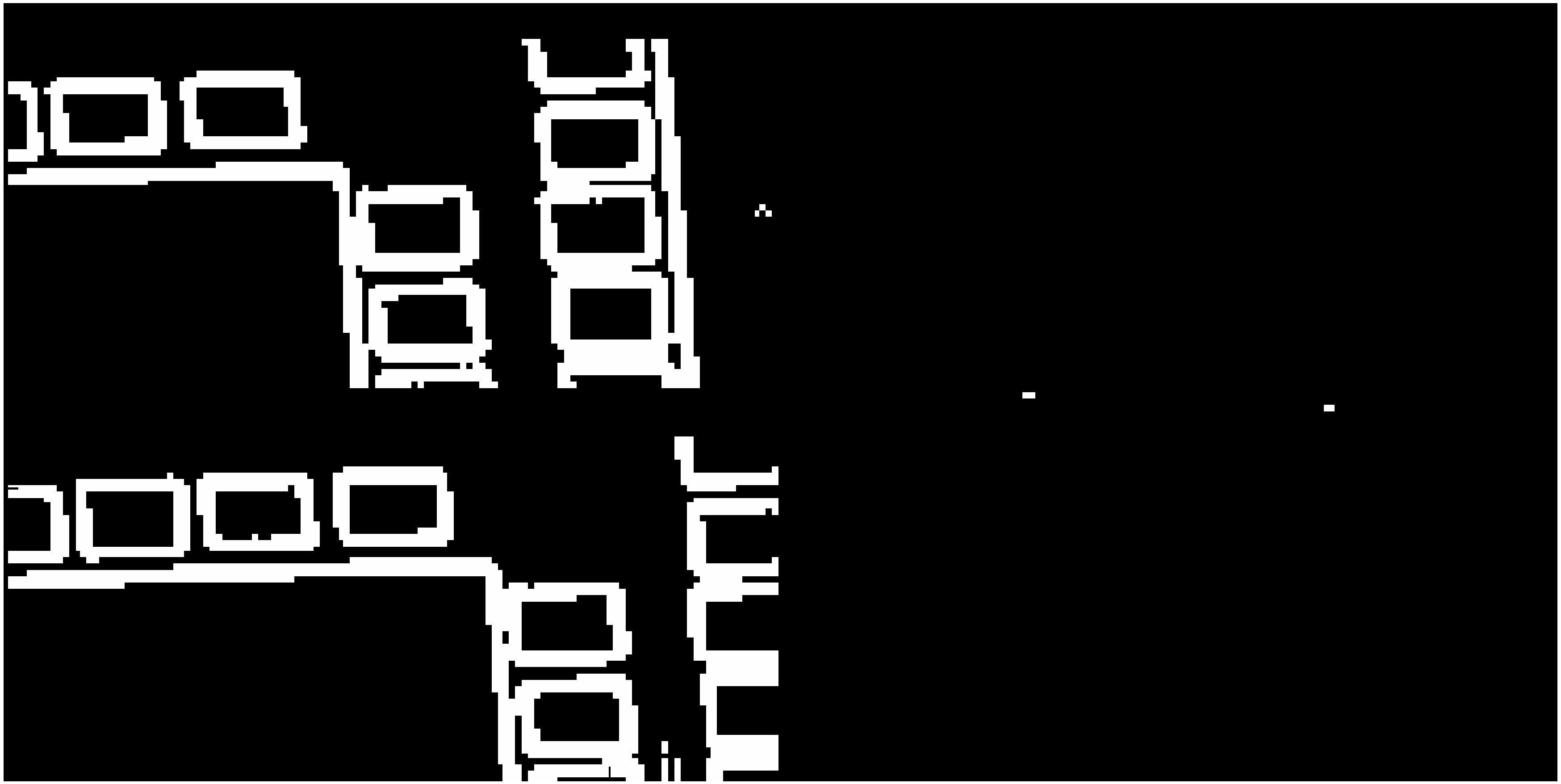
Camera view



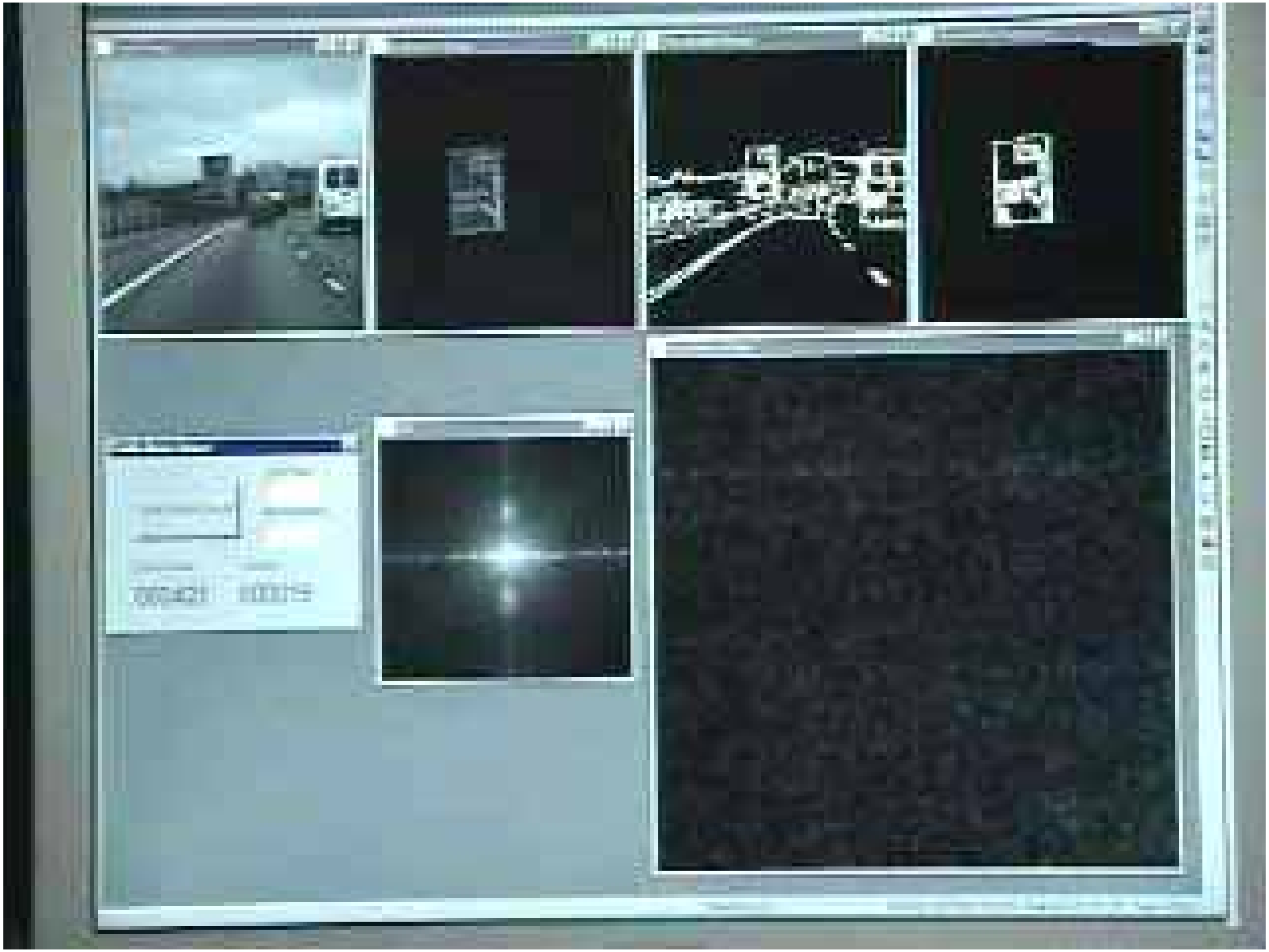


Compare view #1 with view #2



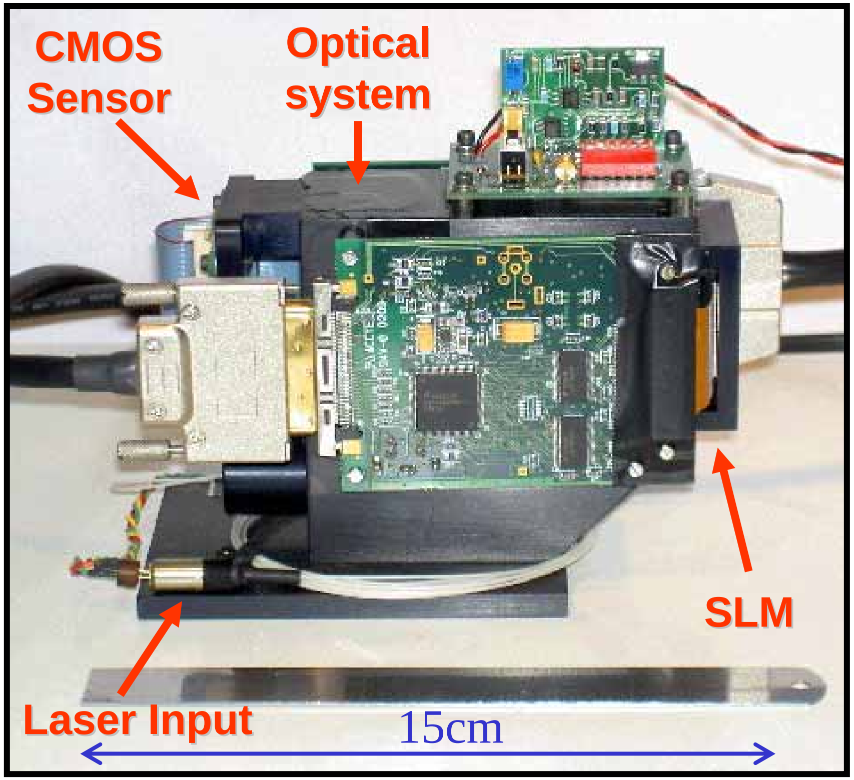


Cambridge Correlators Ltd



The lure of the start-up company

Cambridge Correlators



- Megapixel Resolution
- Capable of over 500 corr/s
- Successfully used in HOVMON field trials
- (Prototype limited by generic drive electronics)