The Lytro Camera
- the Physics and Informatics behind it;

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Financed from the financial support ELTE won from the Higher Education Restructuring Fund of the Hungarian Government

The Camera - Image Formation

- - a photographic camera forms:
- - a real inverted image of an object
- - by a lens or combination of lenses
  - upon the surface of a photographic film or plate;
- - in the absence of aberrations, the image
  - of a distant object
  - which subtends an angle $\delta\theta$
  - at the first nodal points,
  - is of linear dimensions $f\delta\theta$;

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- - that is, in order to produce a large image
  - the focal length must be large;
- - the two main characteristics of a camera are
- - the focal length of its optical system
  - and the range of the focal ratios at which it can operate;
- - another requirement of a camera is that
  - it should cover a large angular field;

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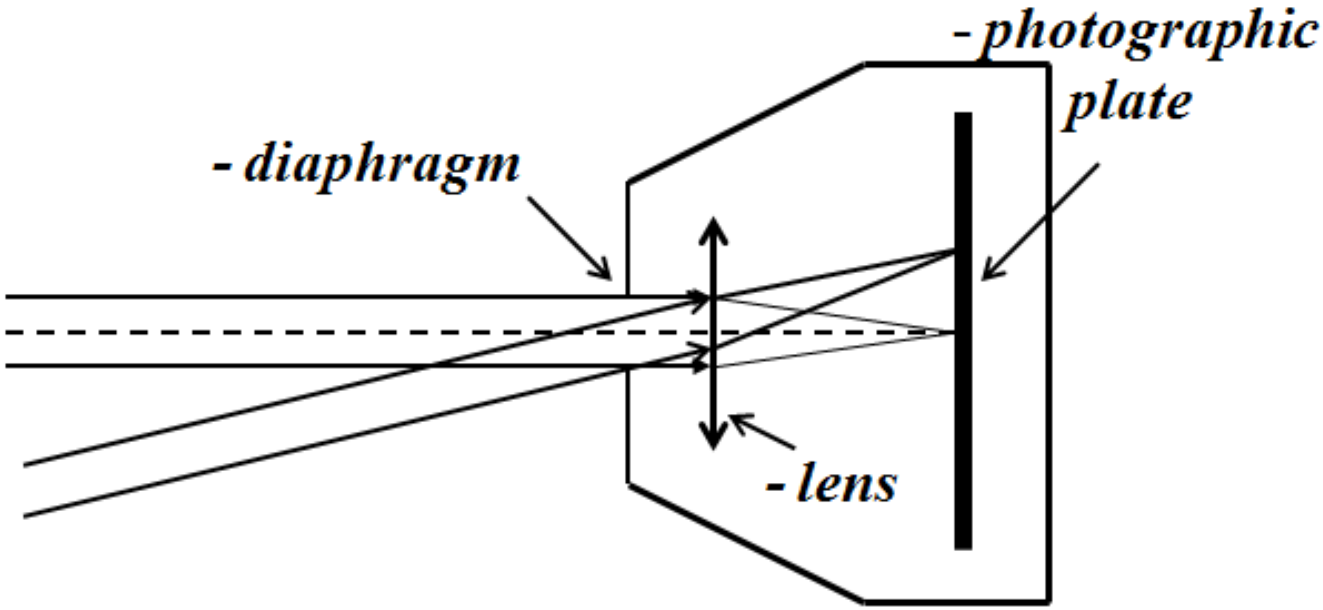
- - the simplest of small cameras use
  - a single convergent lens (as shown in the picture);



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- - in everyday photography one of the major problems is
- - focusing on the subject;
- - though, nowdays modern auto-focus systems provide assistance, still it is not easy to focus accurately;
- - there is a coupling between the aperture size and the depth of field:
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- - the depth of field increases if the aperture size decreases;
- - besides, a narrow aperture moves the blur away from the focal plane;
- - but decreasing the aperture size,
  - requires longer exposure time
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- - so, one of the most important decisions is
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- - another limiting factor is caused by lens aberrations;
- - controlling aberrations is more difficult
  - as the lens aperture increases;
- - modern cameras allow shorter exposures,
  - but still remains the problem of taking pictures
- - at low light levels, like late evenings;

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- - a solution to these problems was given by
- - combining optics with informatics;
- - that is, computing images by using the recorded data;
- - the exponential growth of digital image sensor resolution
  - made it possible to record photographic data
  - and then to process them;
- - a solution to this problem was given by
  - Ren Ng, PhD Thesis, 2006;
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Digital Light Field Photography

- - in Digital Light Field Photography (DLFP)
  - or Lytro Camera,
- - the images are computed instead of being recorded;
  - computation became an integral component of modern photography;
- - digital light field photography uses a
  - microlens array in front of the photosensor;
- - in this DLFP, each microlens covers a small array of photosensor pixels;

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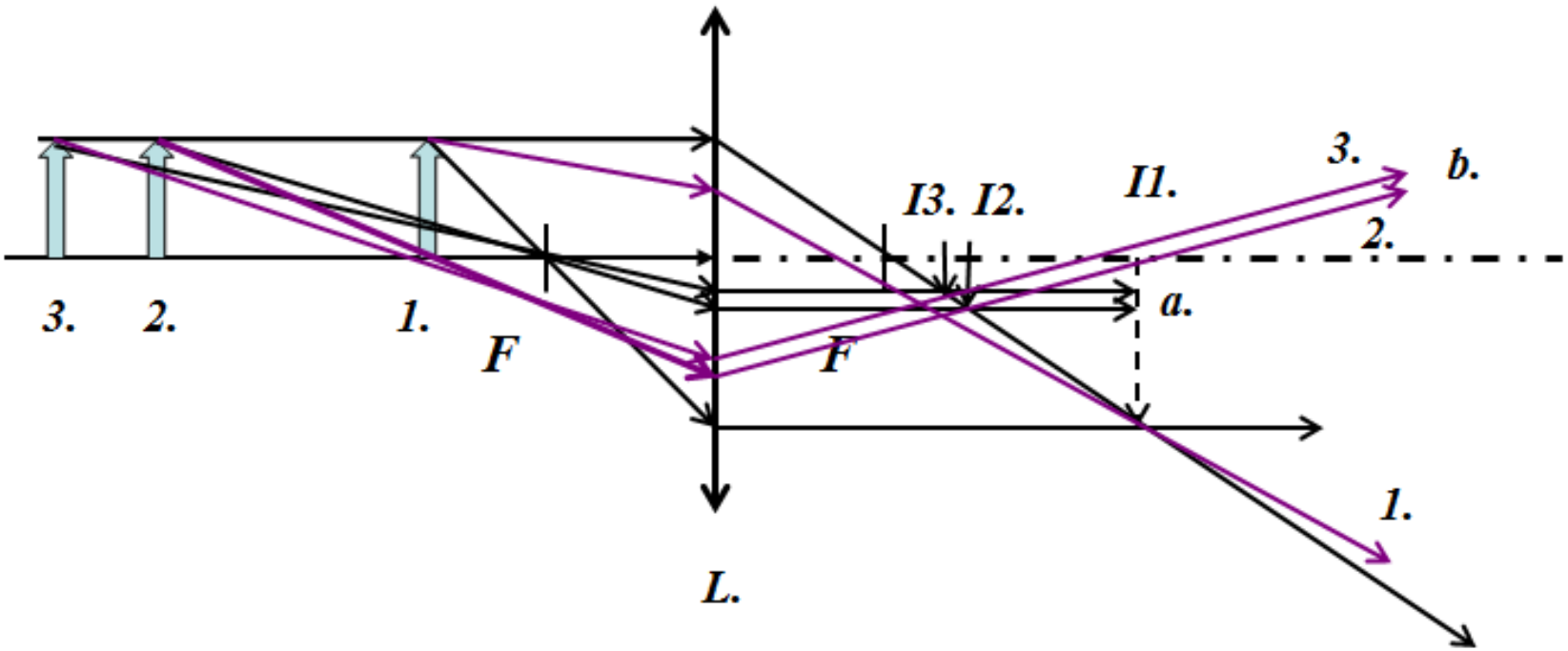
Digital Light Field Photography

- - a microlens should be thought of as an output image pixel;
- - and a photosensor pixel value should be thought of
- - as one of the many light rays that contribute
  - to that output image pixel;
- - let us consider having three objects as in the picture:



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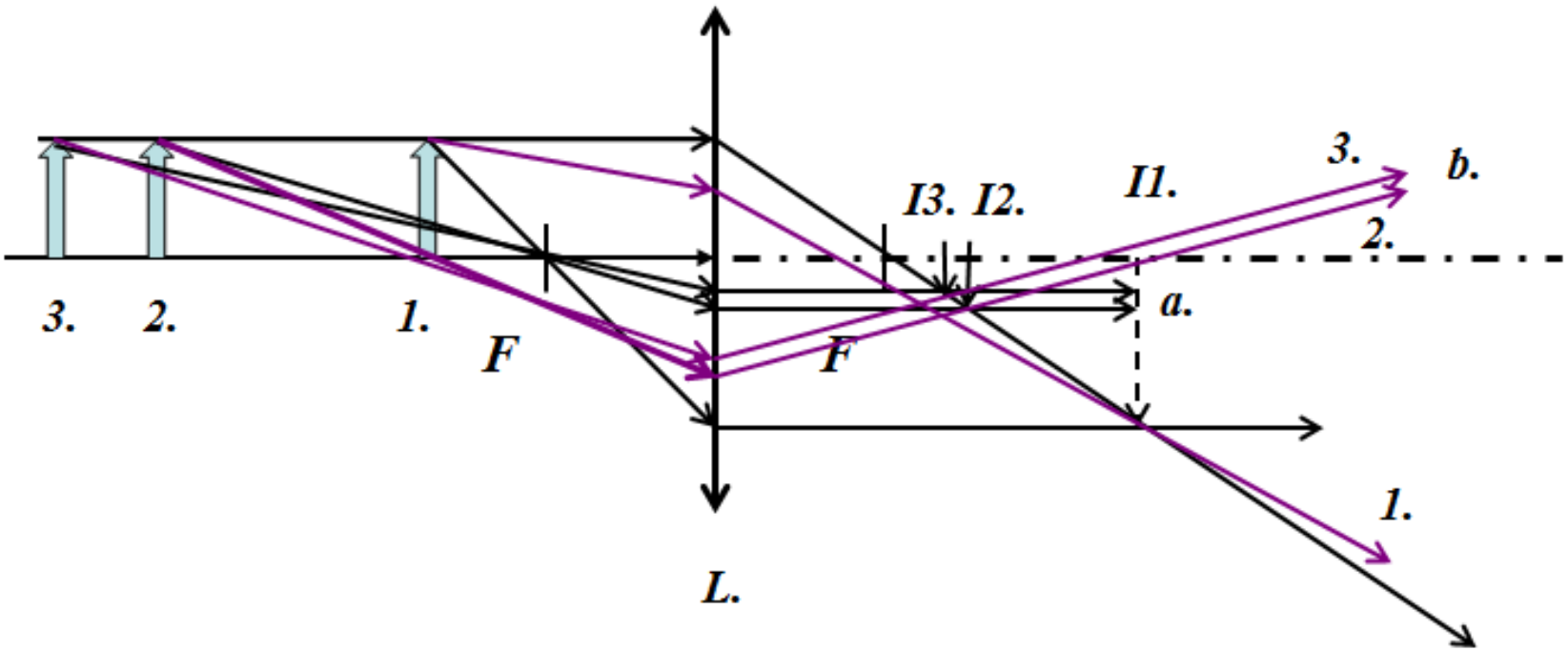

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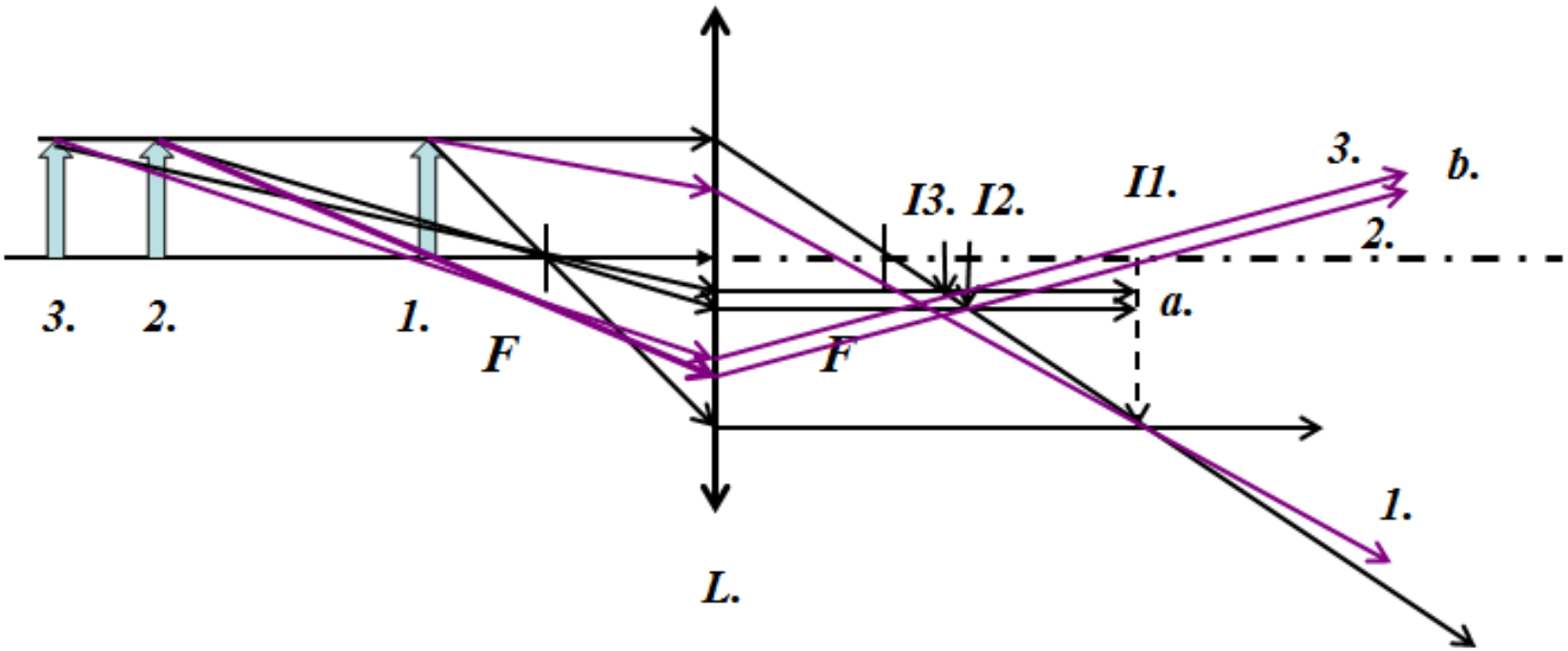

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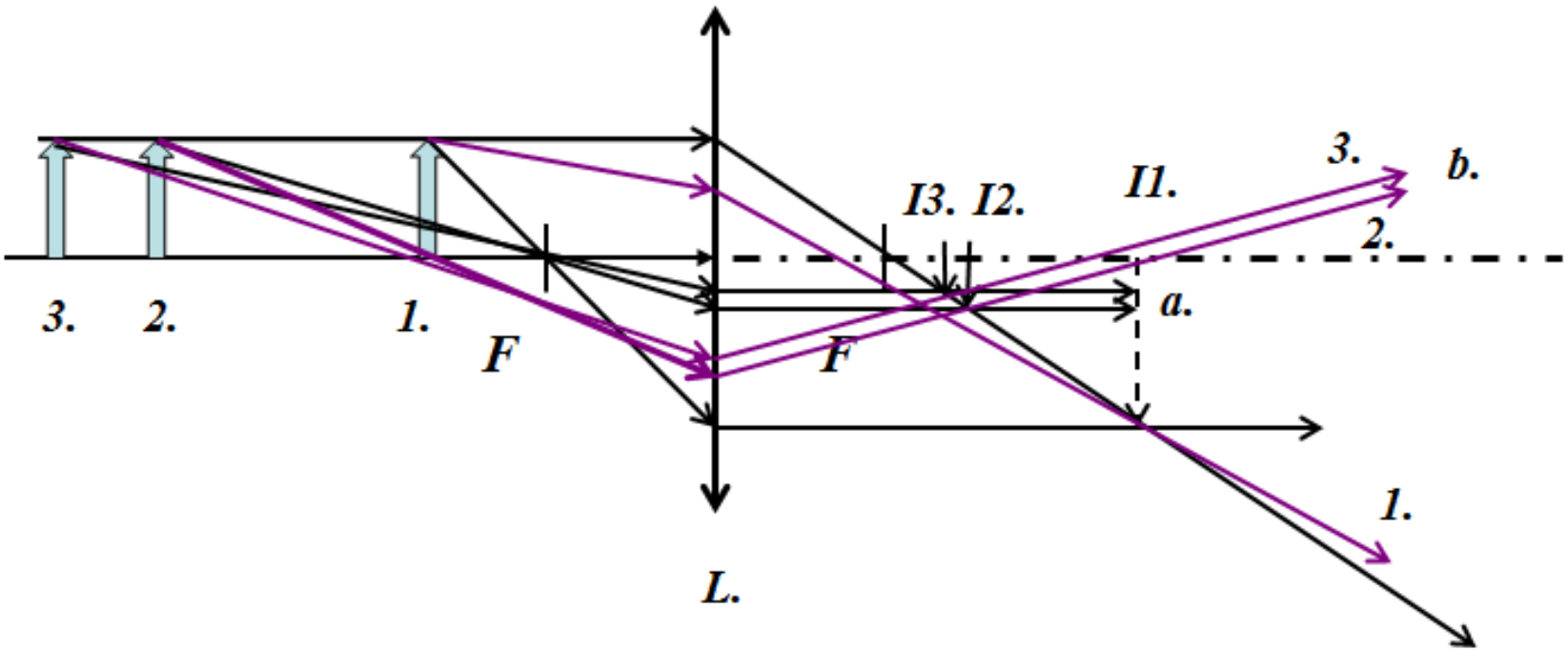

DLFP - Image Formation

- - let us take a picture of these objects
  - in the "scene", by a normal camera;
- - and let us suppose that the photographic plate is in the plane I1
  - in which the first object is imaged by the lens L;
- - the result is that the images of the two distant objects I2 and I3 will not be sharp;
- - let us suppose that a microlens array
  - is inserted between planes I2 and I1;

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- - further, let us exaggerate and suppose that
  - the dimension of a microlens is big enough to
- - collect light rays *a.* and *b.* respectively,
  - coming from the distant objects 2 and 3;
- - if the two objects are very far away,
  - and the distance between them is much smaller then that in the picture
- - these light rays can be considered being parallel;
- - and will be imaged by the same microlense
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- - but taking into consideration that the microlenses
  - are much smaller, one can understand that:
- - if the objects are not too close to each other the light rays *a.* and *b.* will be imaged by different microlenses on different photosensor pixels;
- - that is, each microlens sees the object in the scene from a different direction, and images on the pixels underneath;
- - in this way, in addition to intensity,
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- - as known from holography,
  the extra knowledge of the direction makes it possible to reconstruct the object;
- - in this case, the extra knowledge of the direction allows the calcualtion of the image without focusing on it;
- - the microlenses are microscopic compared to the main lens, and so is the gap between the microlenses and the photosensor;

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