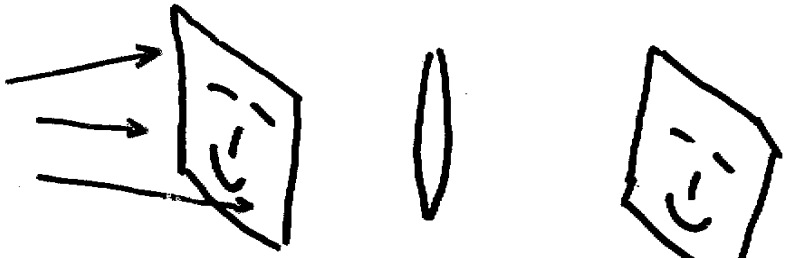
Illuminators

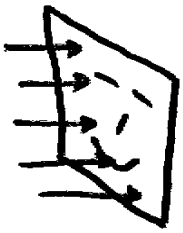
Typically, images do not come from self-

- objects are not self-luminous
- objects are illuminated by another source



object
(transparency,
for example)

Ideal illuminator source: a bright planar source of uniform brightness

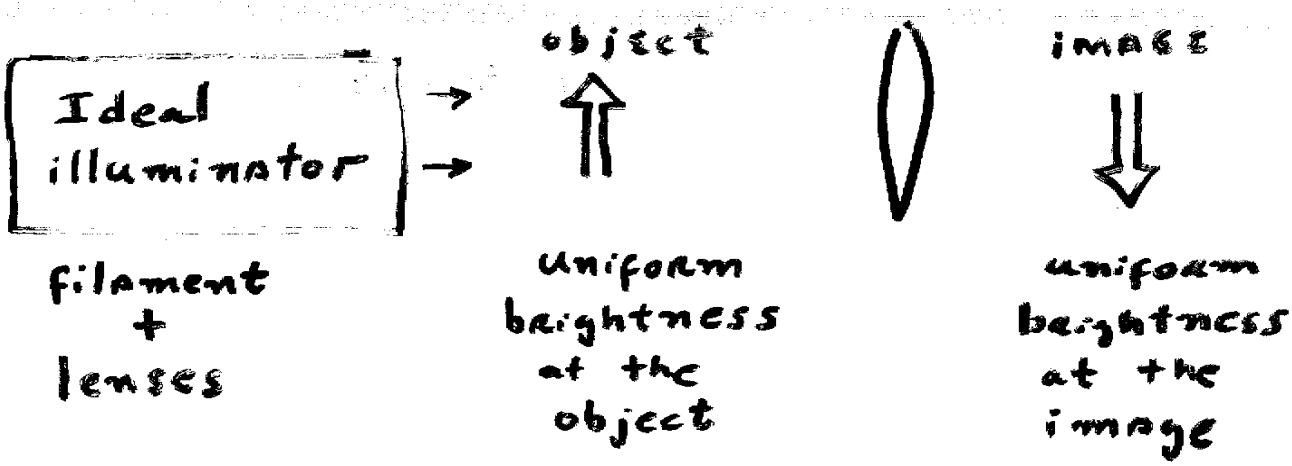


object

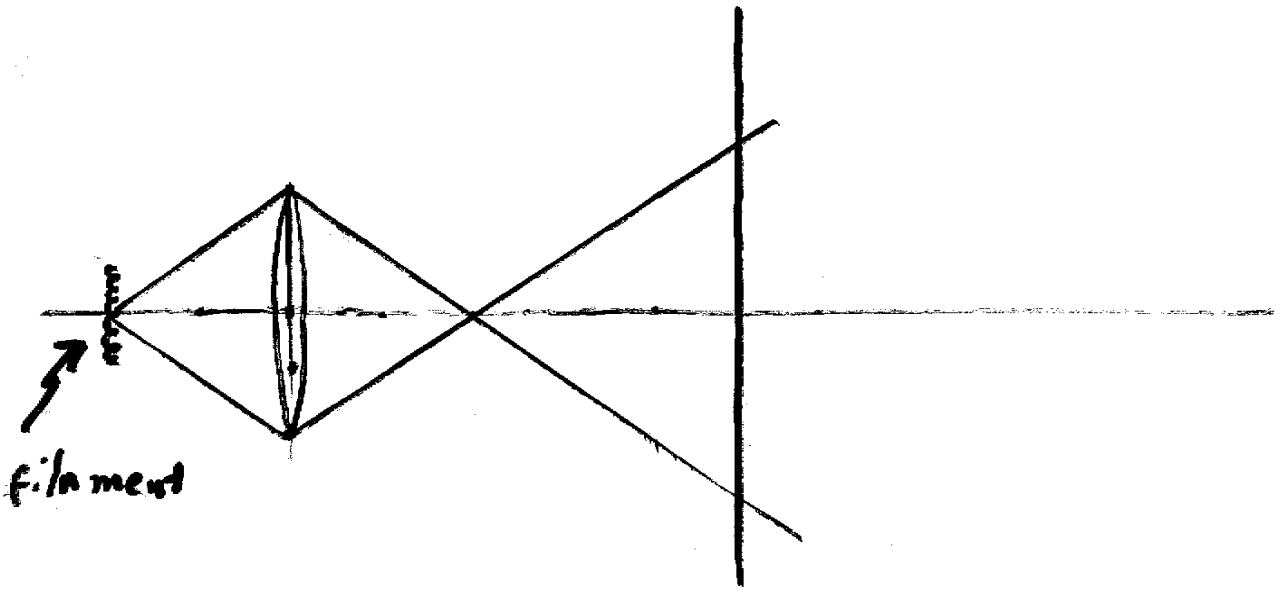
However, such a source is not available. A

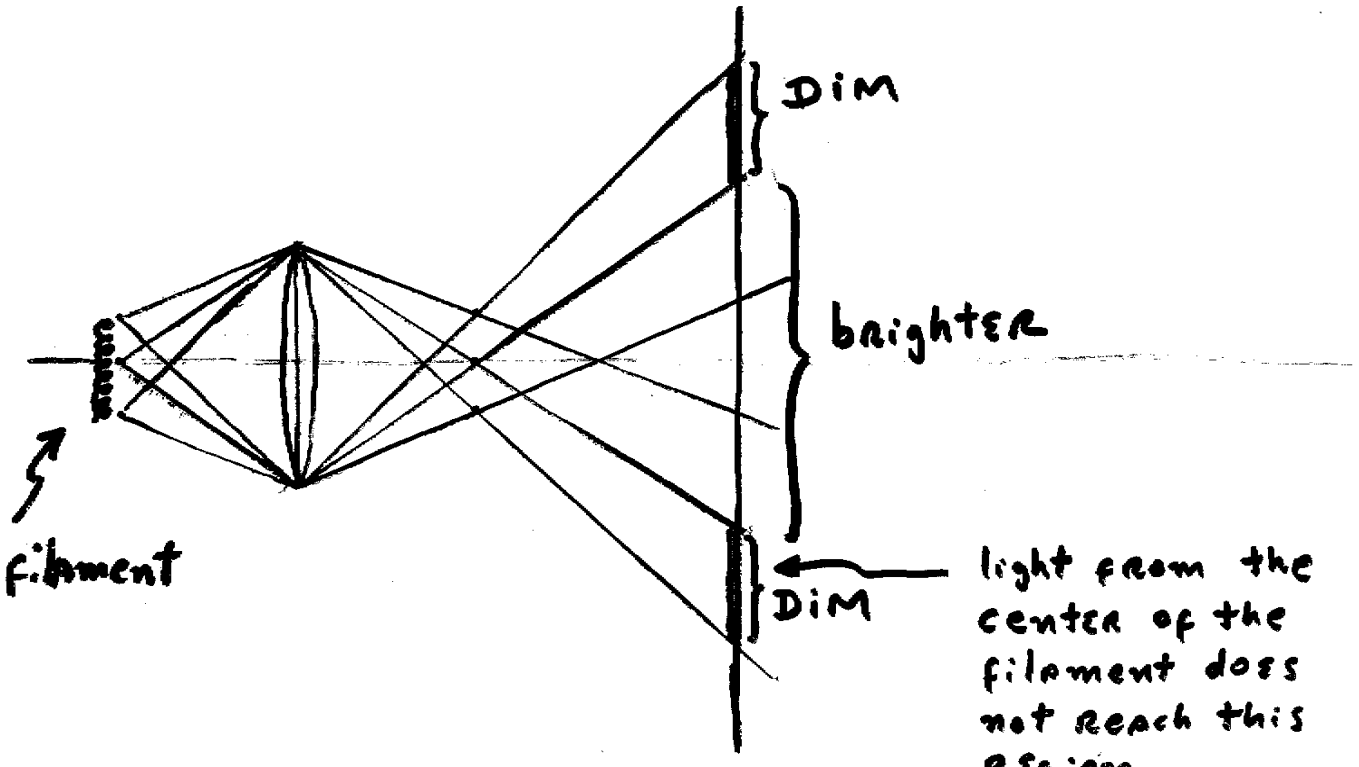
Filament tightly wound still does not produce a uniform-brightness illumination.

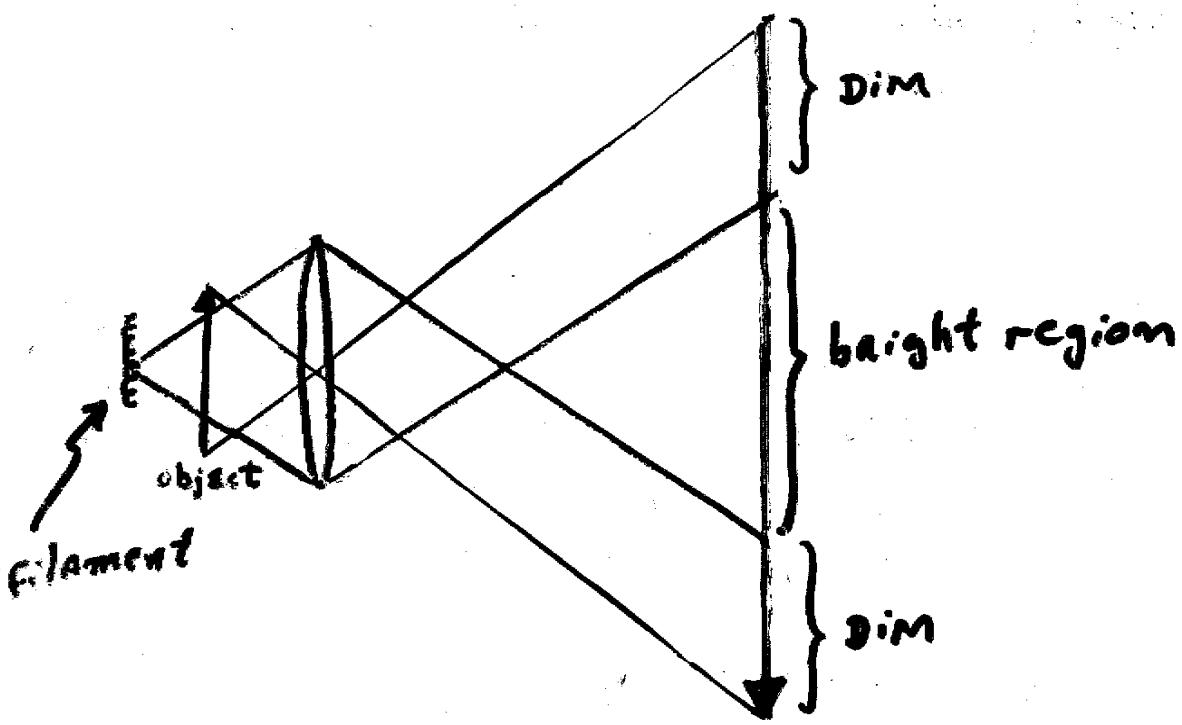
THEREFORE: some optics must be engineered.


Ideal
illuminator
object
image
filament
+
lenses
uniform
brightness
at the
object
uniform
brightness
at the
image

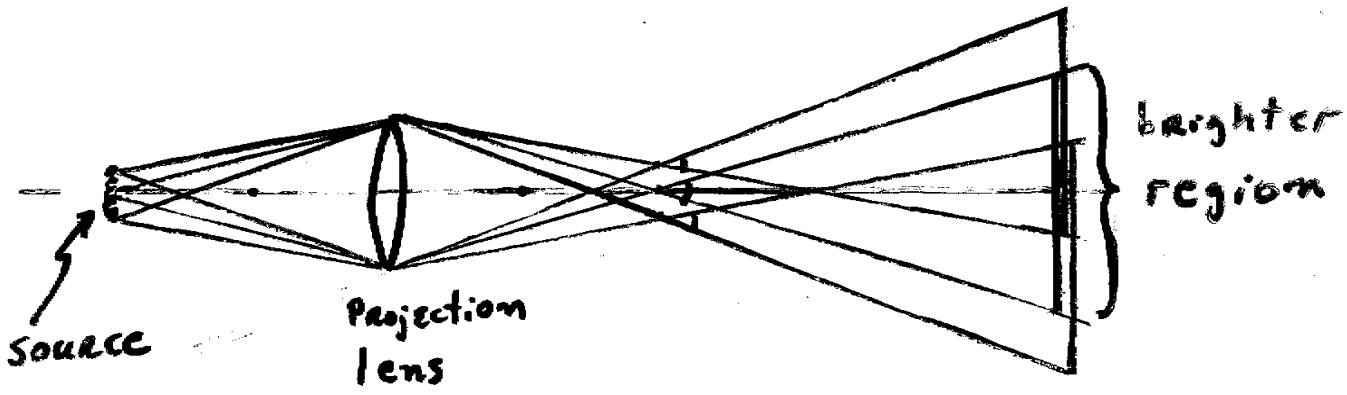
EXAMPLE An inexpensive projector





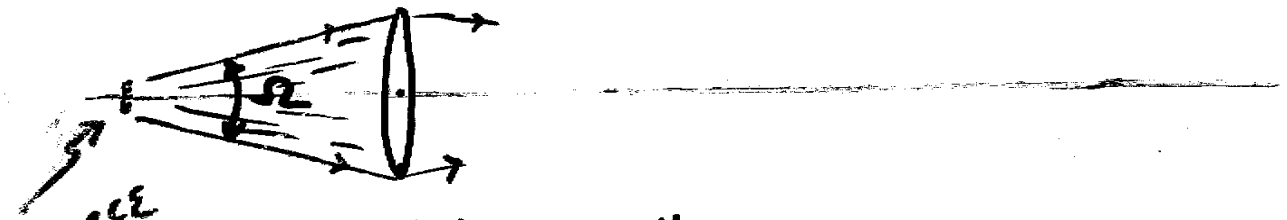

DIM
bright region
DIM
lens
object
filament

drawback



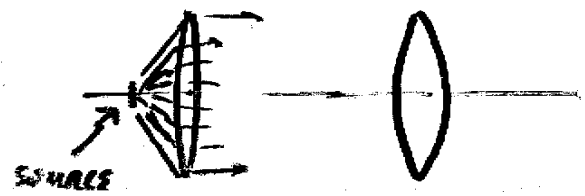
uneven illumination

drawback

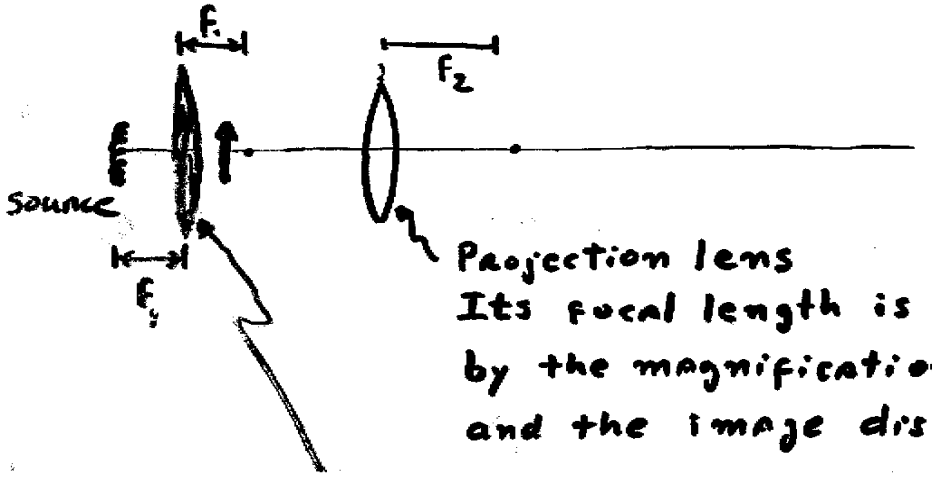


only a relative small cone angle is used for the illumination

alternative, to use a lens to collect the maximum amount of light from the source



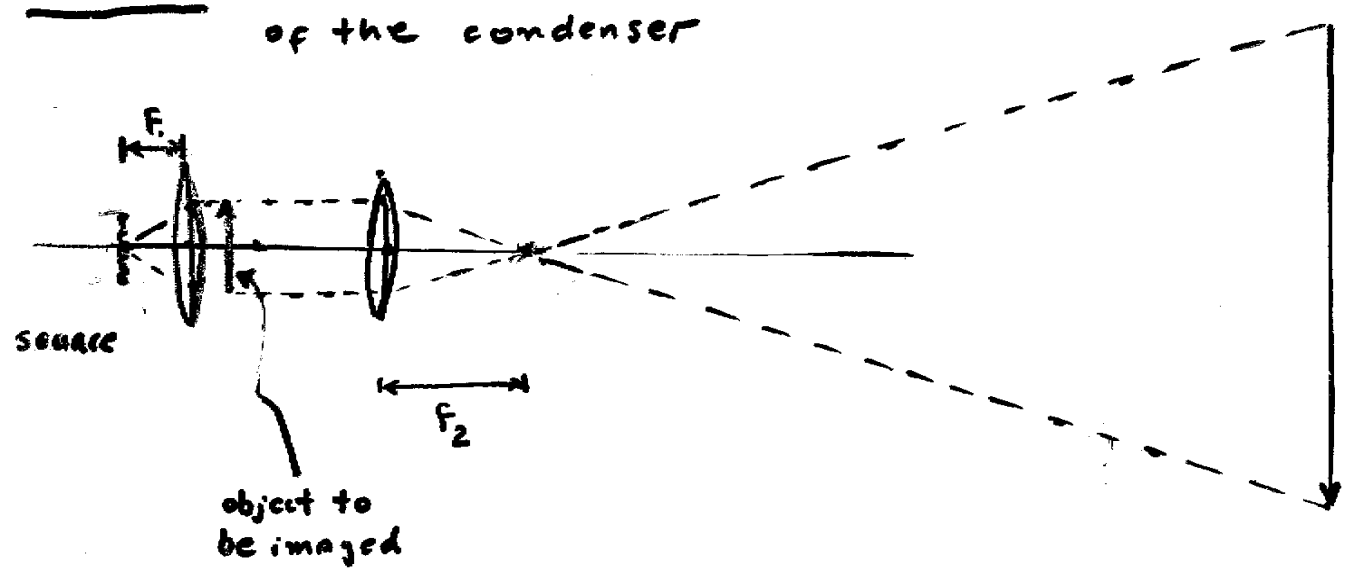
INCREASING THE ILLUMINATION WITH A "CONDENSER LENS"



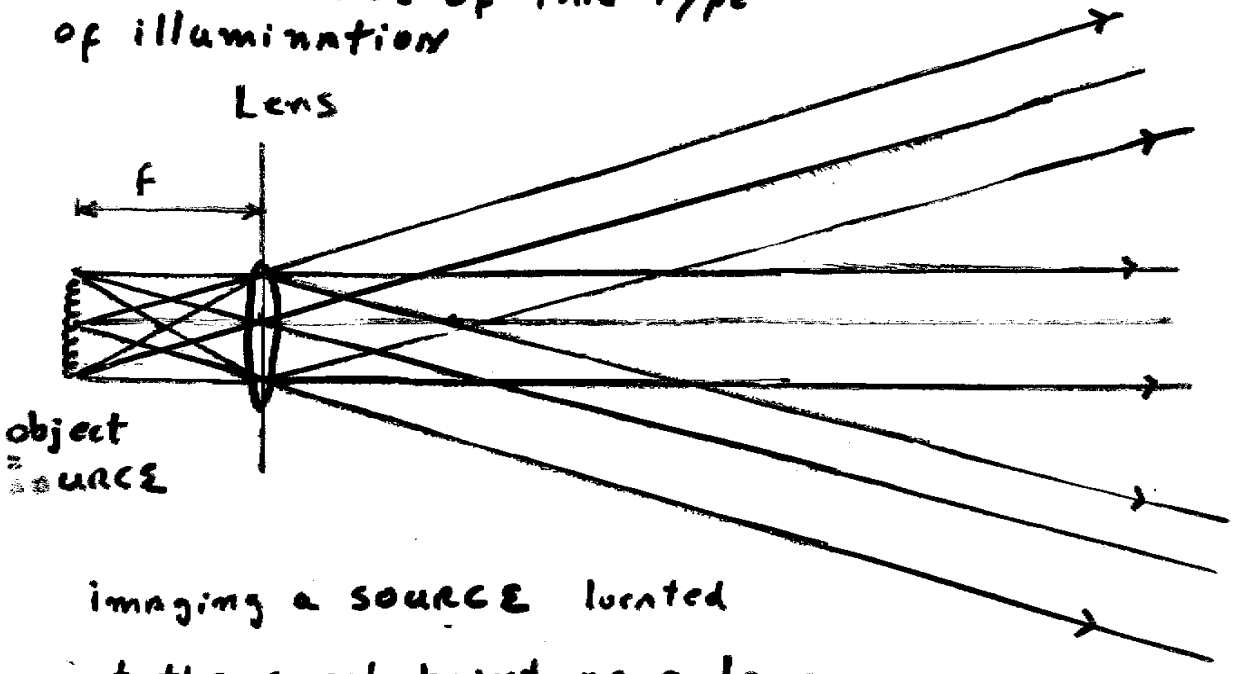
Projection lens
Its focal length is determined by the magnification needed and the image distance

condenser lens
Its focal length is made as short as possible and its diameter as large as possible

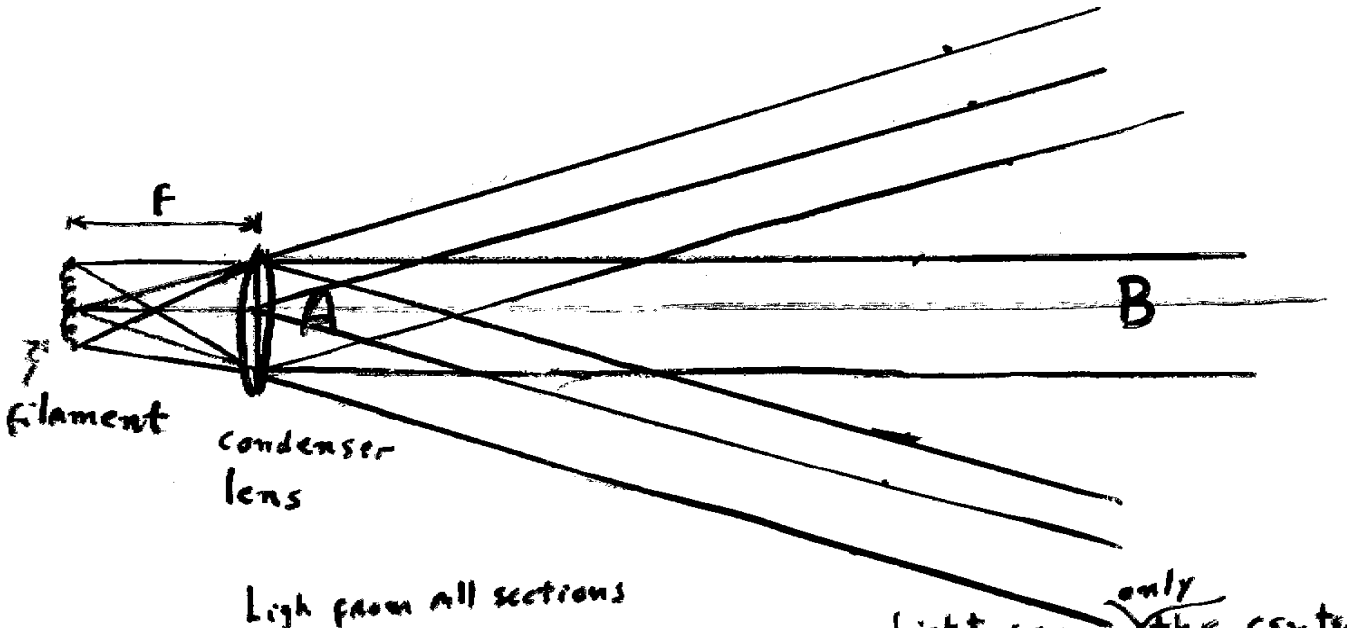
CASE-I Source located at the focal point of the condenser



Characteristics of this type of illumination



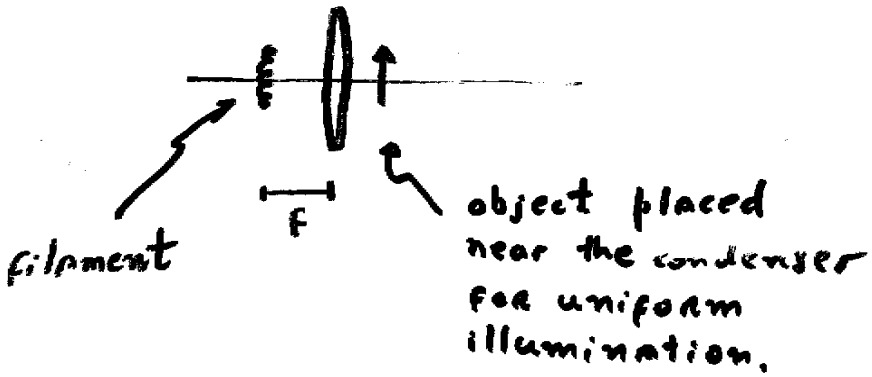
imaging a SOURCE located at the focal point of a lens



Ligh from all sections of the filament reach region A

Light from only the center of the filament reaches region B

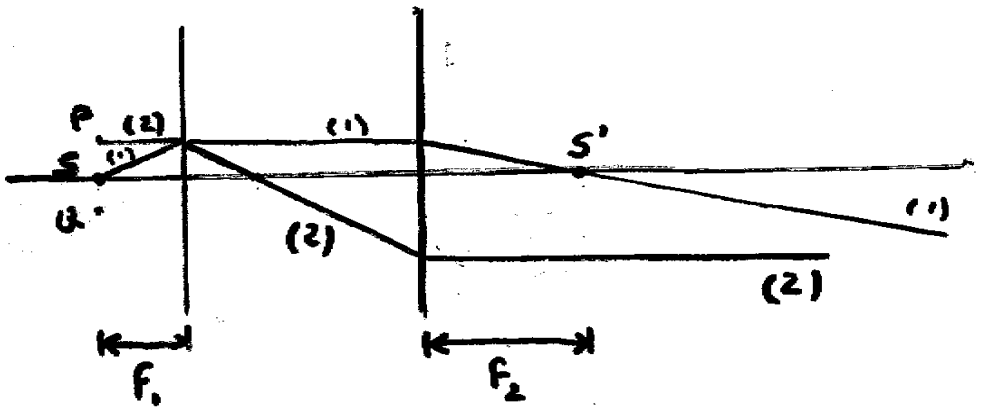
Thus, it will be convenient to place an object nearby the condenser lens (region A) where the illumination is more uniform (with all parts of the filament contributing to the illumination)



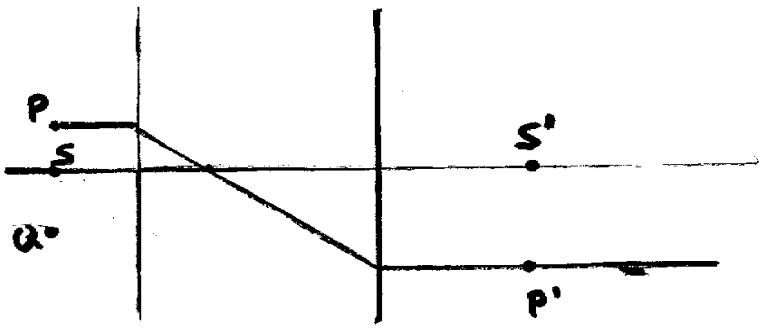
Let's consider now what happens when we place the projection lens

To simplify the analysis, let's consider the particular case where the condenser (F_1) and the projection (f_2) lenses are separated by a distance $F_1 + f_2$

First, let's locate the position of the filament's image

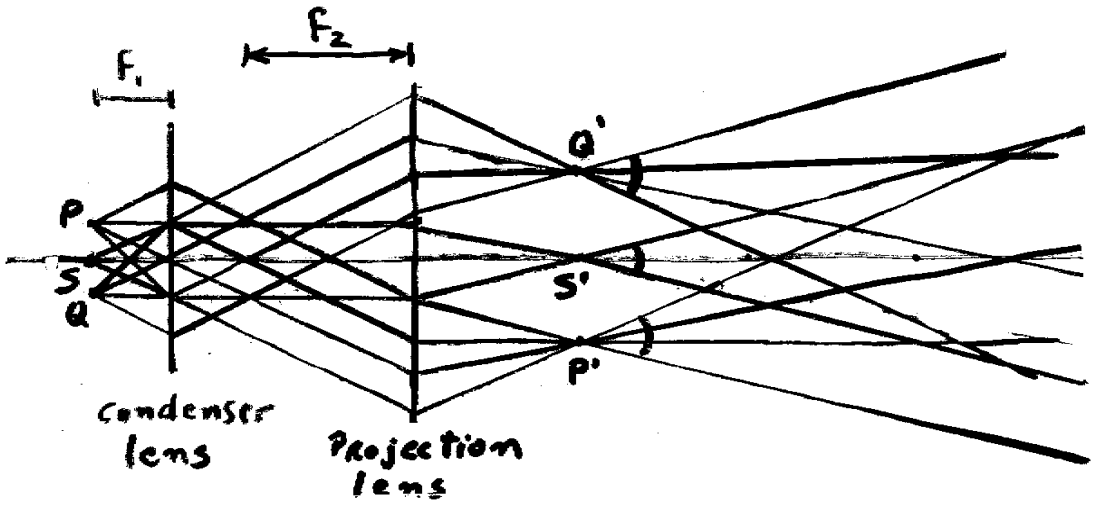


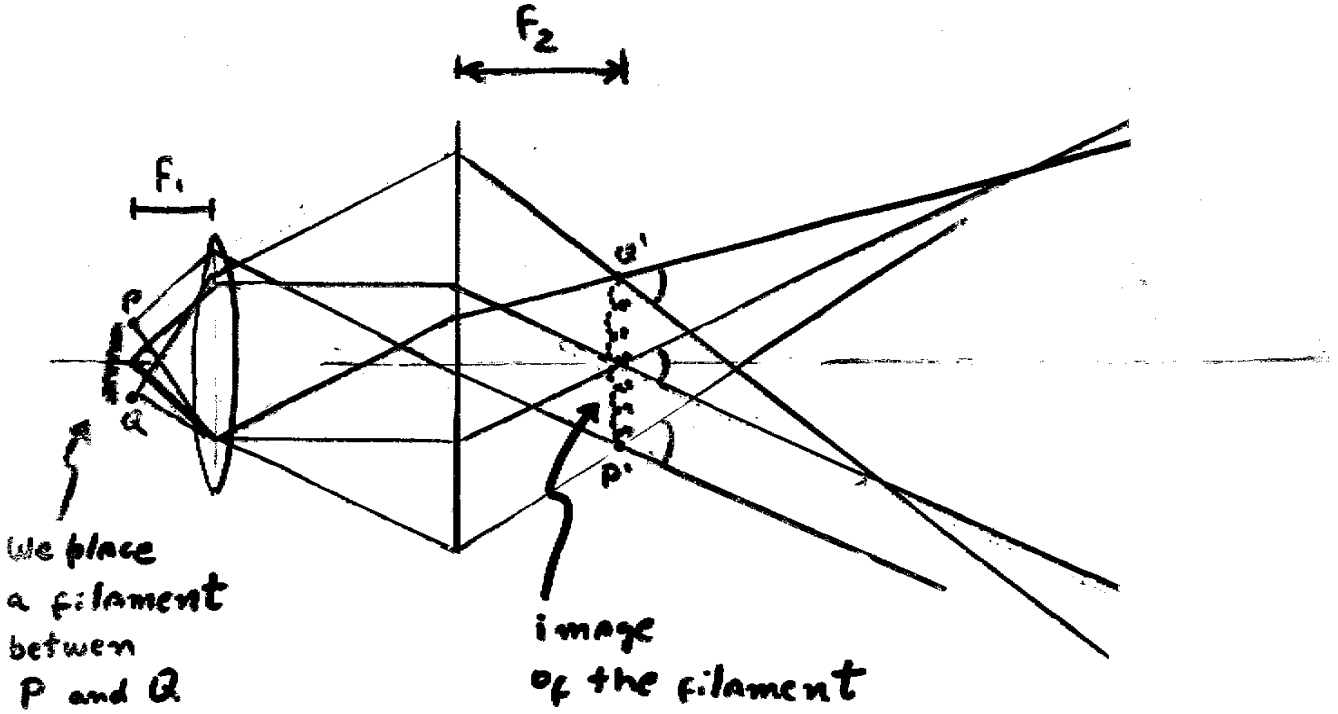
Once the image point S' is identified, the image of point P should lie in the plane that passes by T'



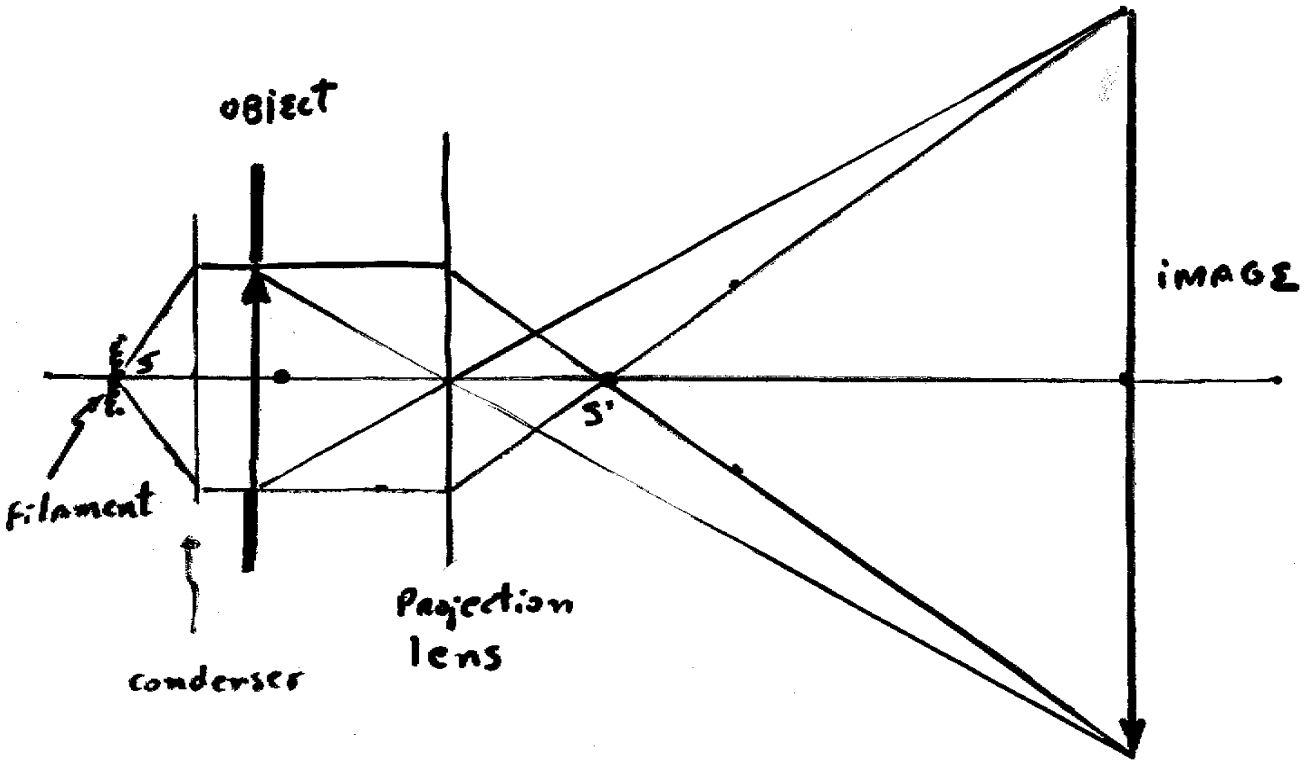
we passed similarly to find the image of point Q

Having identified the image points P' and Q', it is much easier to trace ANY other RAY (which we do in the following two diagrams)


F2
F1
Q'
P
S
Q
S'
P'
condenser lens
Projection lens

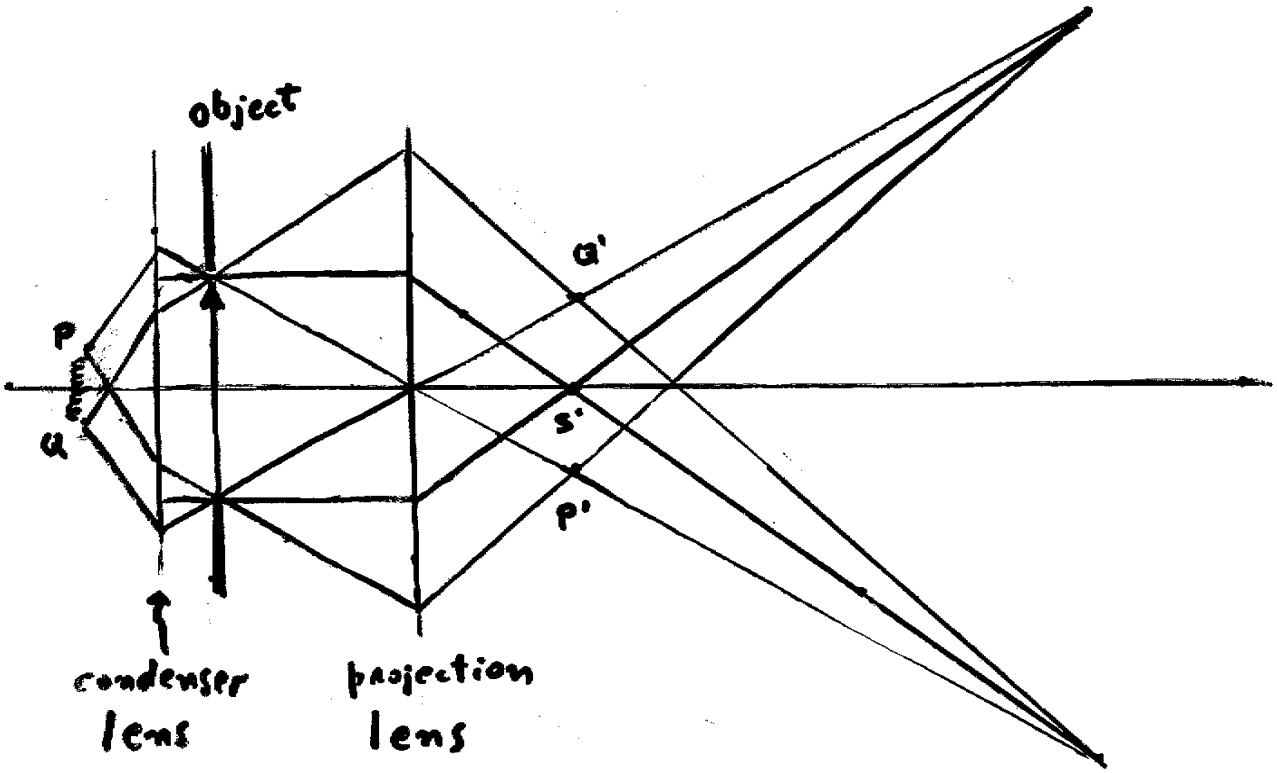

F2
F1
Q'
P
Q
P'
We place a filament between P and Q
image of the filament

In the middle of the illumination pattern we have just outlined in the previous two graphs, we place an OBJECT (a slide with its frame)



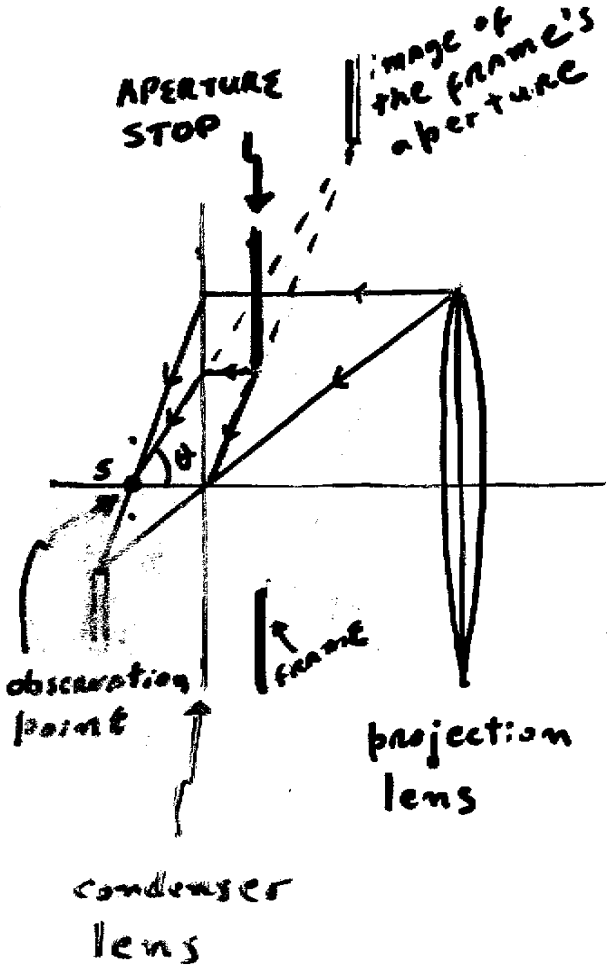
Notice: the central part of the filament illuminates evenly the whole object and the full image.

Uneven illumination on the image plane may come when considering other parts of the filament

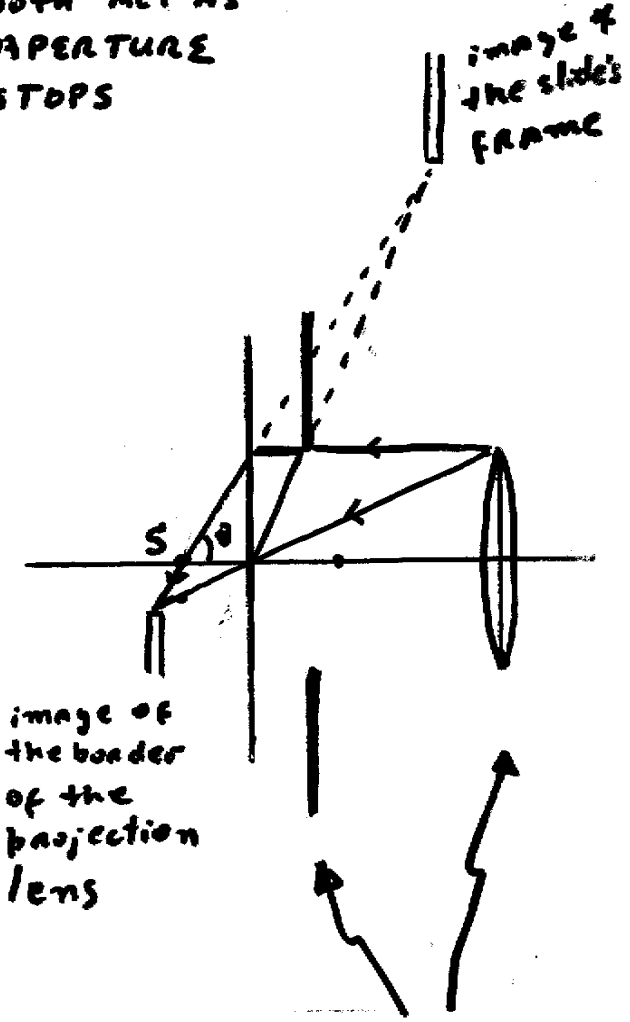


Drawback: If the projection lens is not big enough the illumination will suffer from vignetting

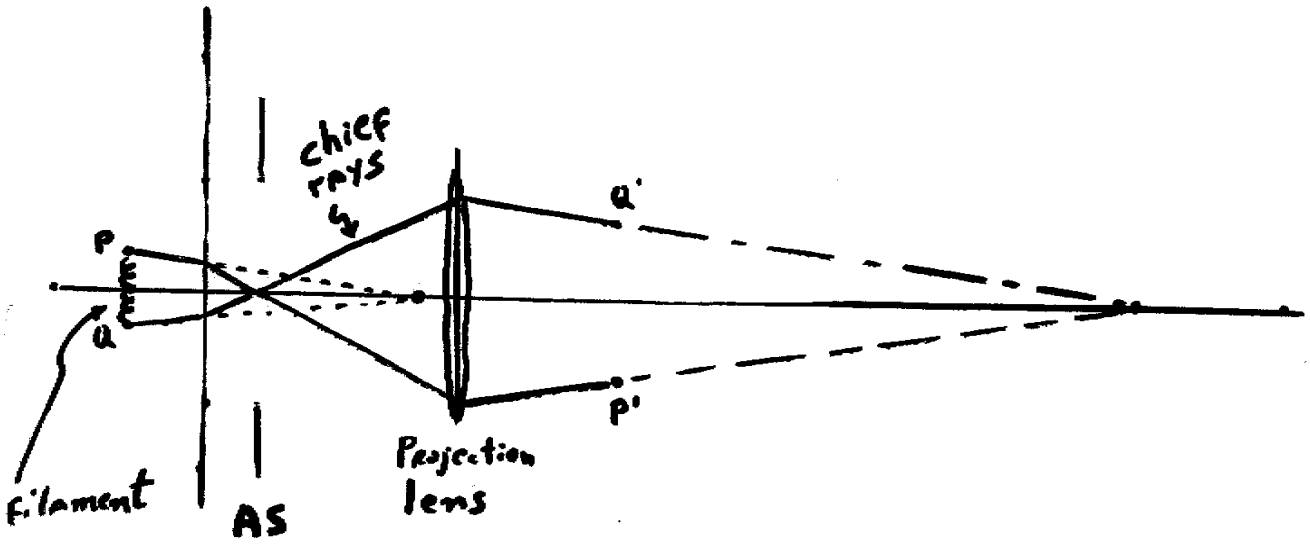
As far as the projection lens is bigger than the frame's aperture, the latter acts as the APERTURE STOP



Just, out of curiosity, notice that is the projection lens' rim is equal to the frame's aperture both act as APERTURE STOPS

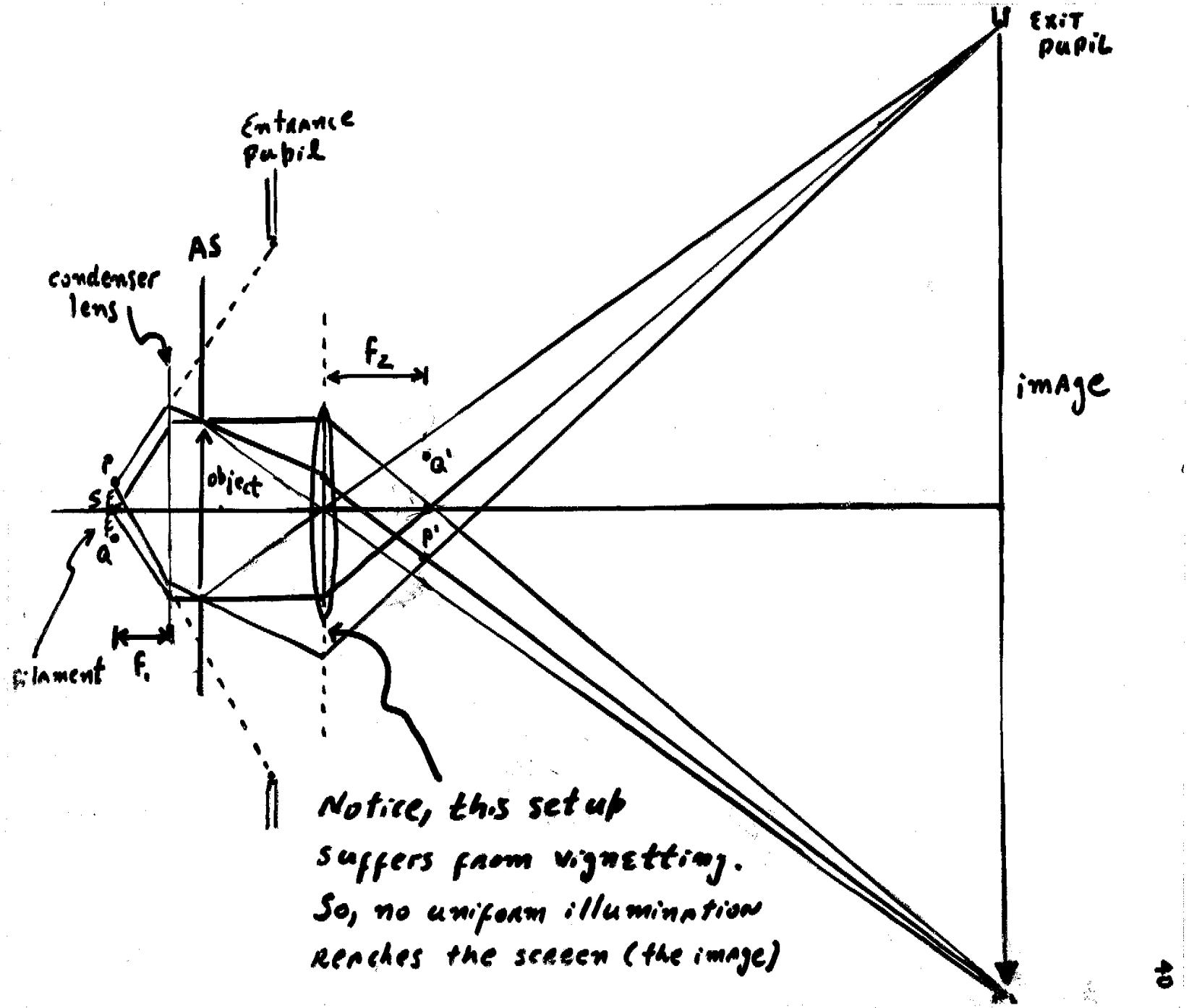


Notice, both act as APERTURE STOP



Entrance pupil

Exit pupil


Exit pupil
Entrance pupil
AS
condenser lens
F_2
image
object
P
S
Q
'Q'
P'
filament
F_1
Notice, this set up suffers from vignetting. So, no uniform illumination reaches the screen (the image)

Looking at the previous diagram, we wonder if there will be a way to avoid vignetting (i.e. a way to obtain uniform illumination on the image plane)

A key aspect in finding a solution is to look carefully at the filament's image. (The filament's image is indicated by the segment P'Q' in all the previous diagrams)

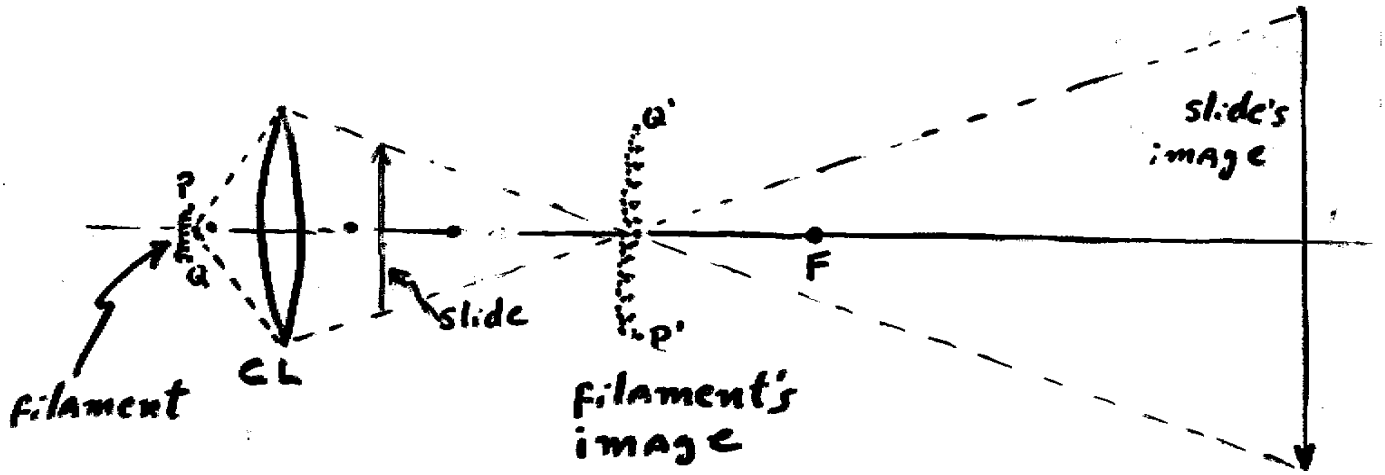
We realize that vignetting occurs mainly because of the finite size of the projection lens

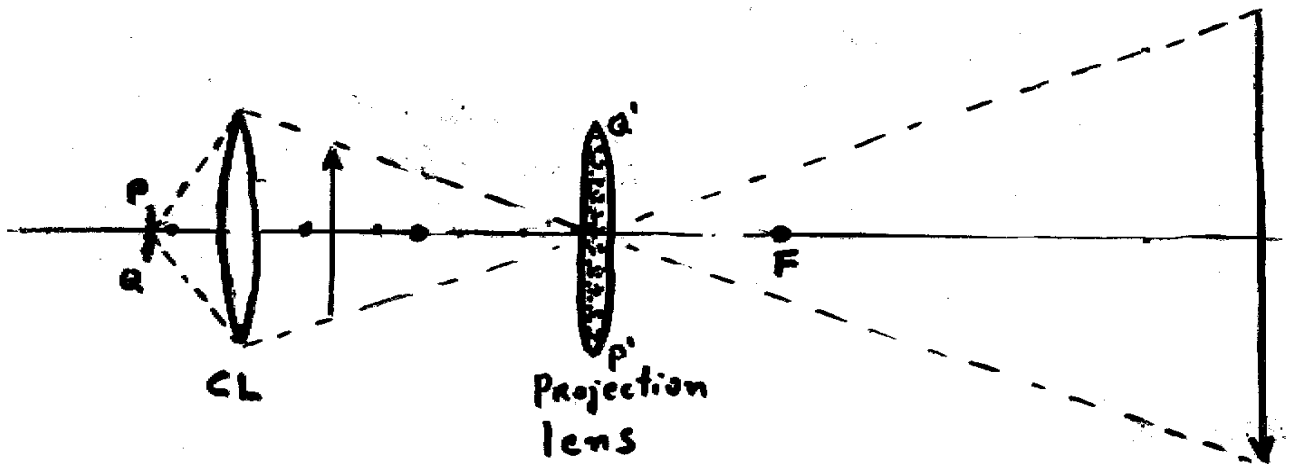
Notice!
What about if we managed to put P'Q' inside the projection lens. If that happened we would get rid of of vignetting.!

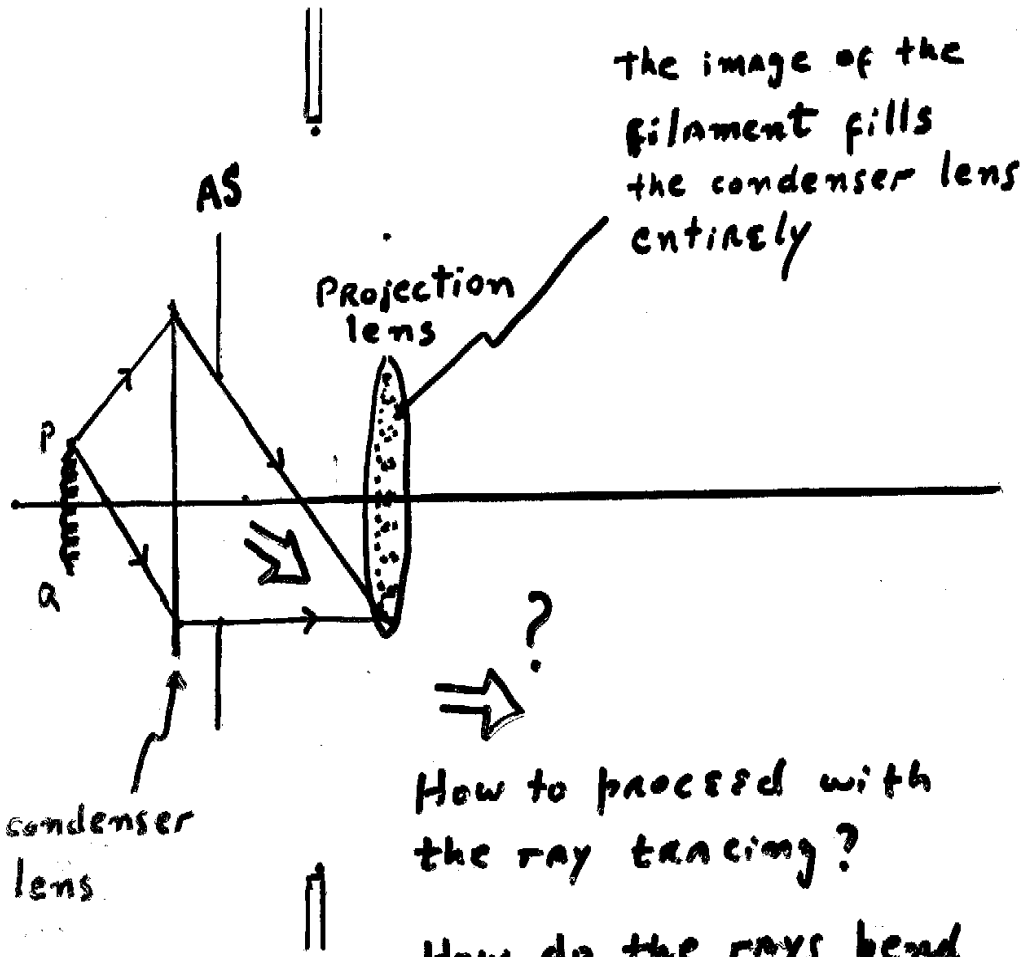
What can we do to end up with filament's image P'Q' inside the projection lens ?

Example-3 Köhler Illumination

Compared to the previous case, let's move the source further back from the condenser lens until a magnified image of the source appears at the projection lens







the image of the filament fills the condenser lens entirely

⇒ ?

How to proceed with the ray tracing?

How do the rays bend upon their arrival at the projection lens?

For the projection lens:

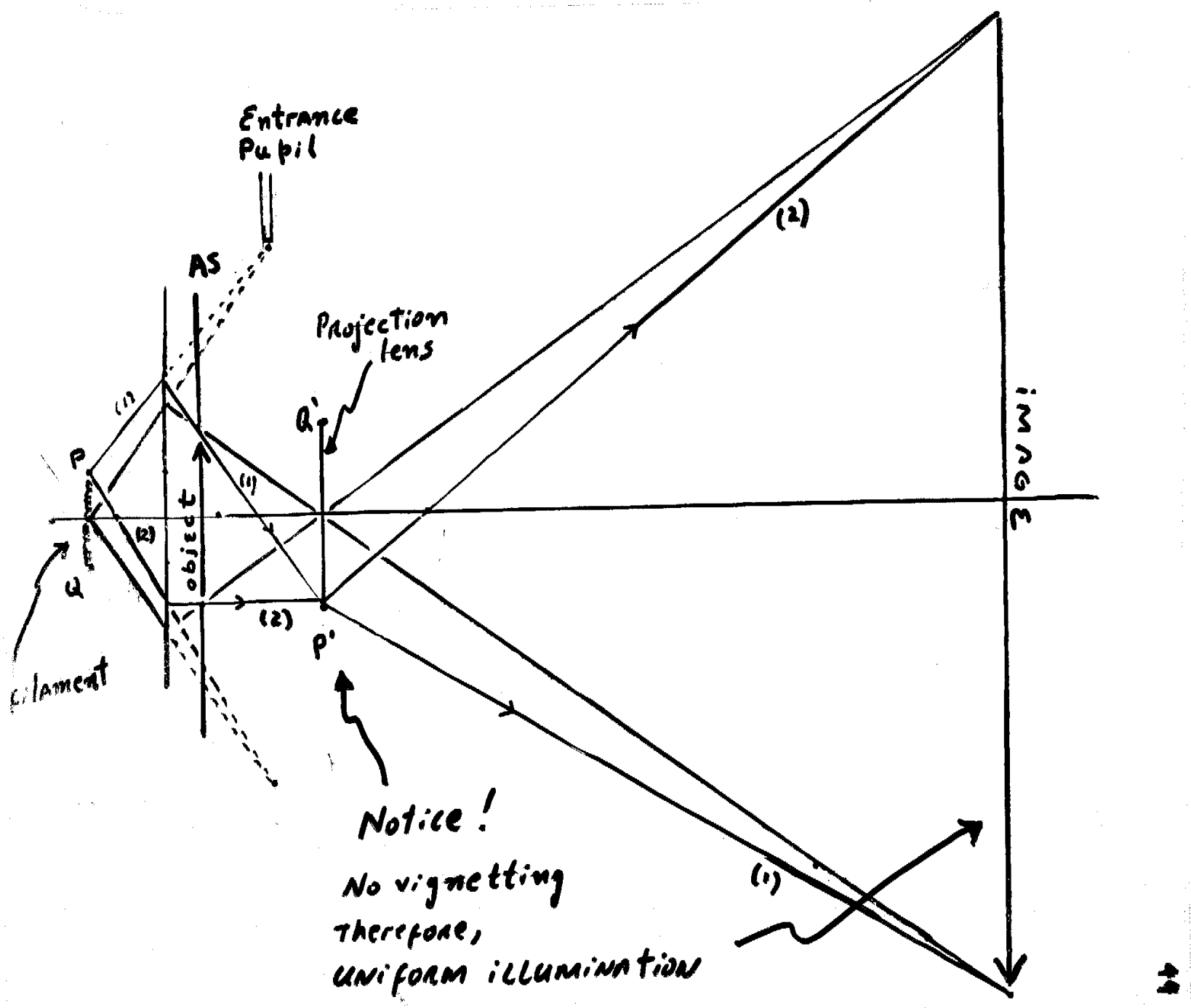
It receives an object at $s_o = 0$.

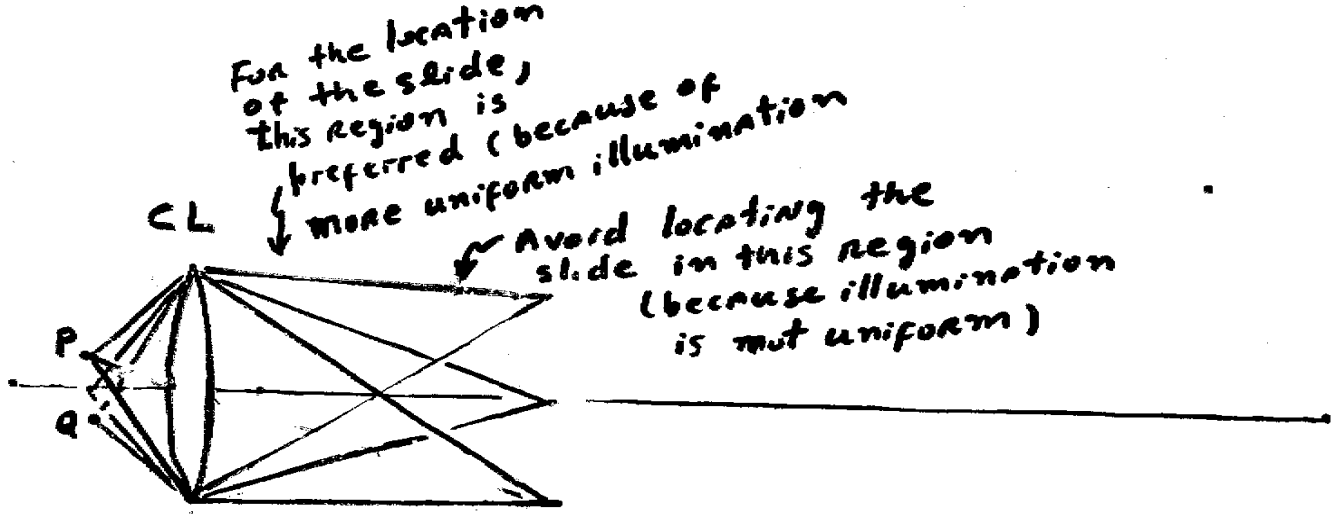
Since

$$\frac{1}{s_o} + \frac{1}{s_i} = \frac{1}{f_2}$$

therefore

$$s_i = 0 \quad \text{also.}$$

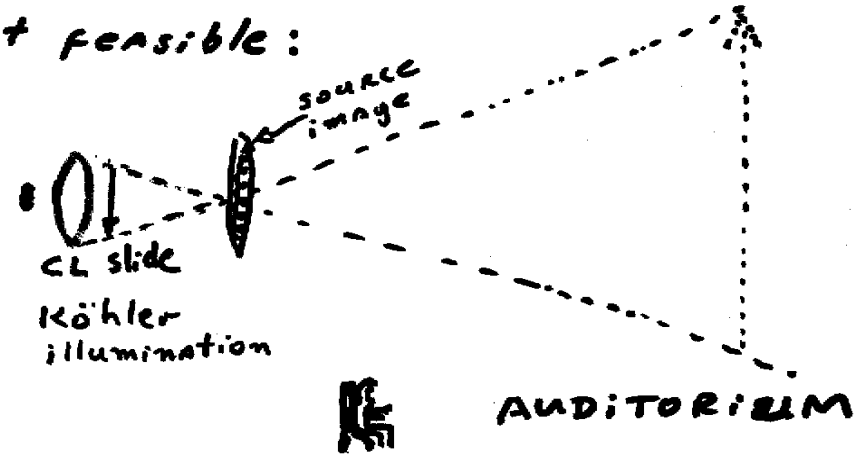

Entrance Pupil
AS
Projection lens
Q'
P
(1)
(2)
object
Q
filament
(2)
P'
(2)
image
(1)
Notice !
No vignetting
therefore,
uniform illumination


For the location of the slide, this region is preferred (because of more uniform illumination
CL
Avoid locating the slide in this region (because illumination is not uniform)
P
Q

PQ: filament

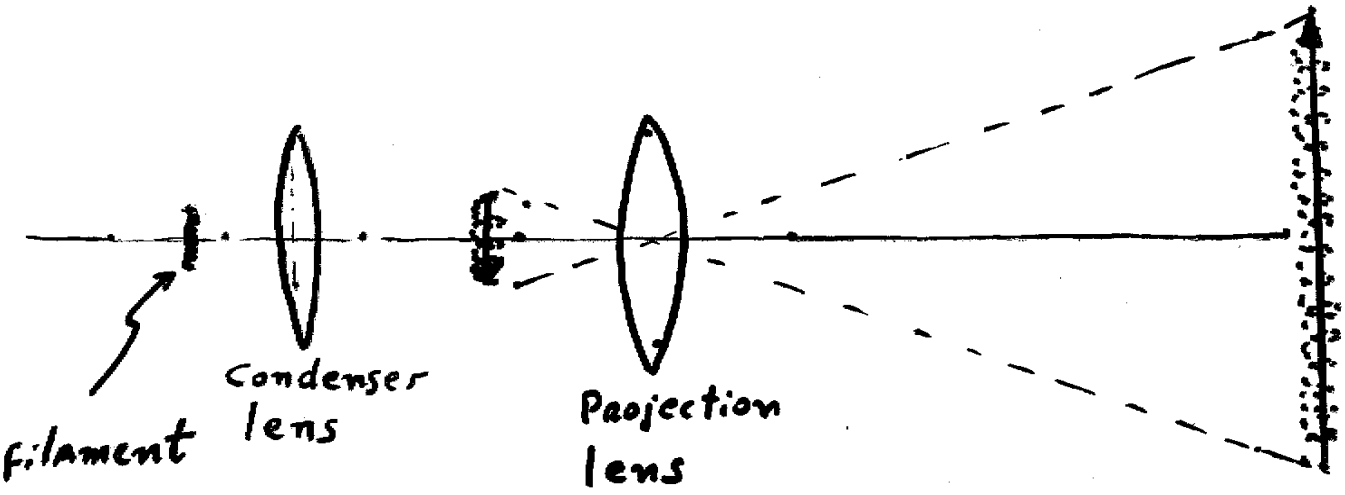
Example-4 Abbe Illumination

There are conditions where Köhler illumination is not feasible:



By placing the slide in the constant irradiance region of the condenser lens, the illuminnation may not be high enough to project it into the screen.

An alternative is to place the source image onto the location of the slide (being careful not to burn the slide!). So, we back up the filament source a little bit from the CL.



We gain radiant power from the object being imaged, but
unless the filament brightness is extremely uniform, its irregularities will be evident on the screen

A solution for this draw back is to make the condenser slightly irregular to produce a uniformly blurred filament's image