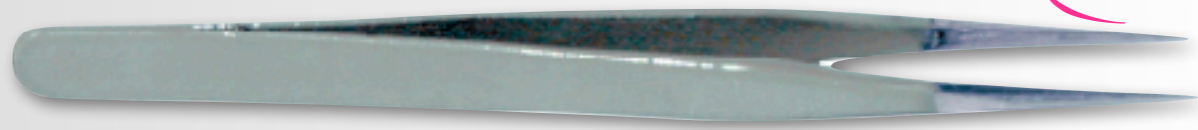


# Optical tweezers



- ▶ Who, when
- ▶ What
- ▶ Why
- ▶ **How**



# *Arthur Ashkin*

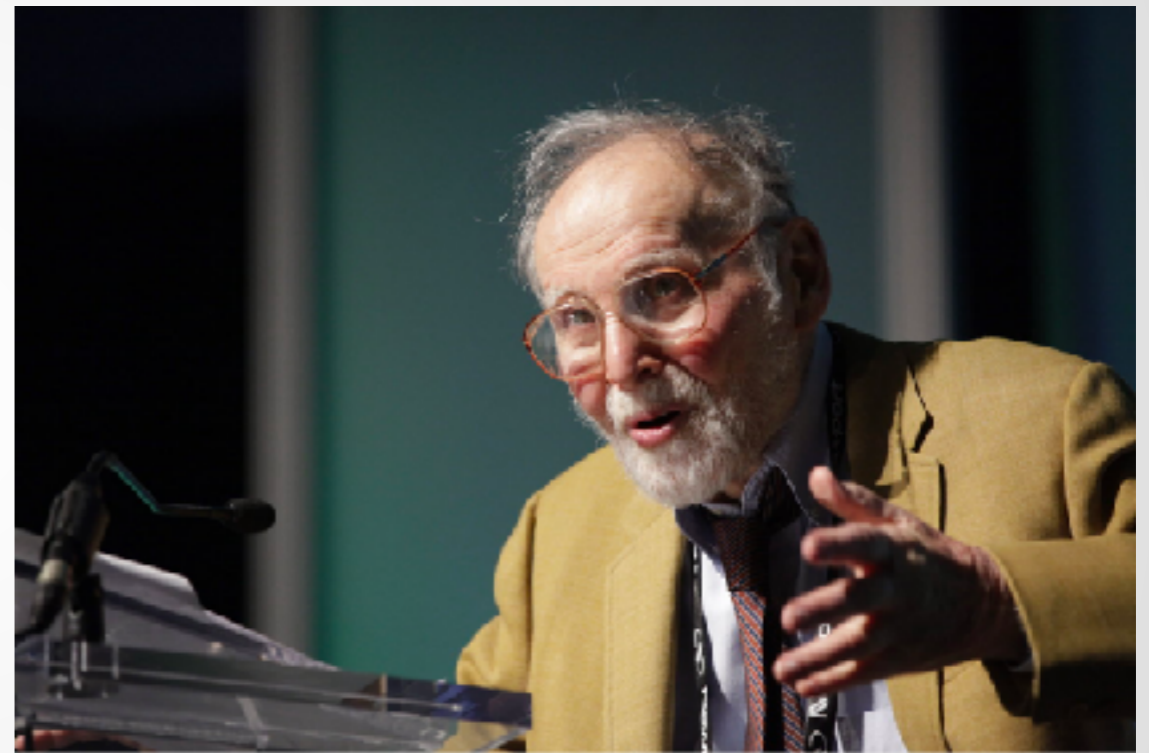
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American, born 1922

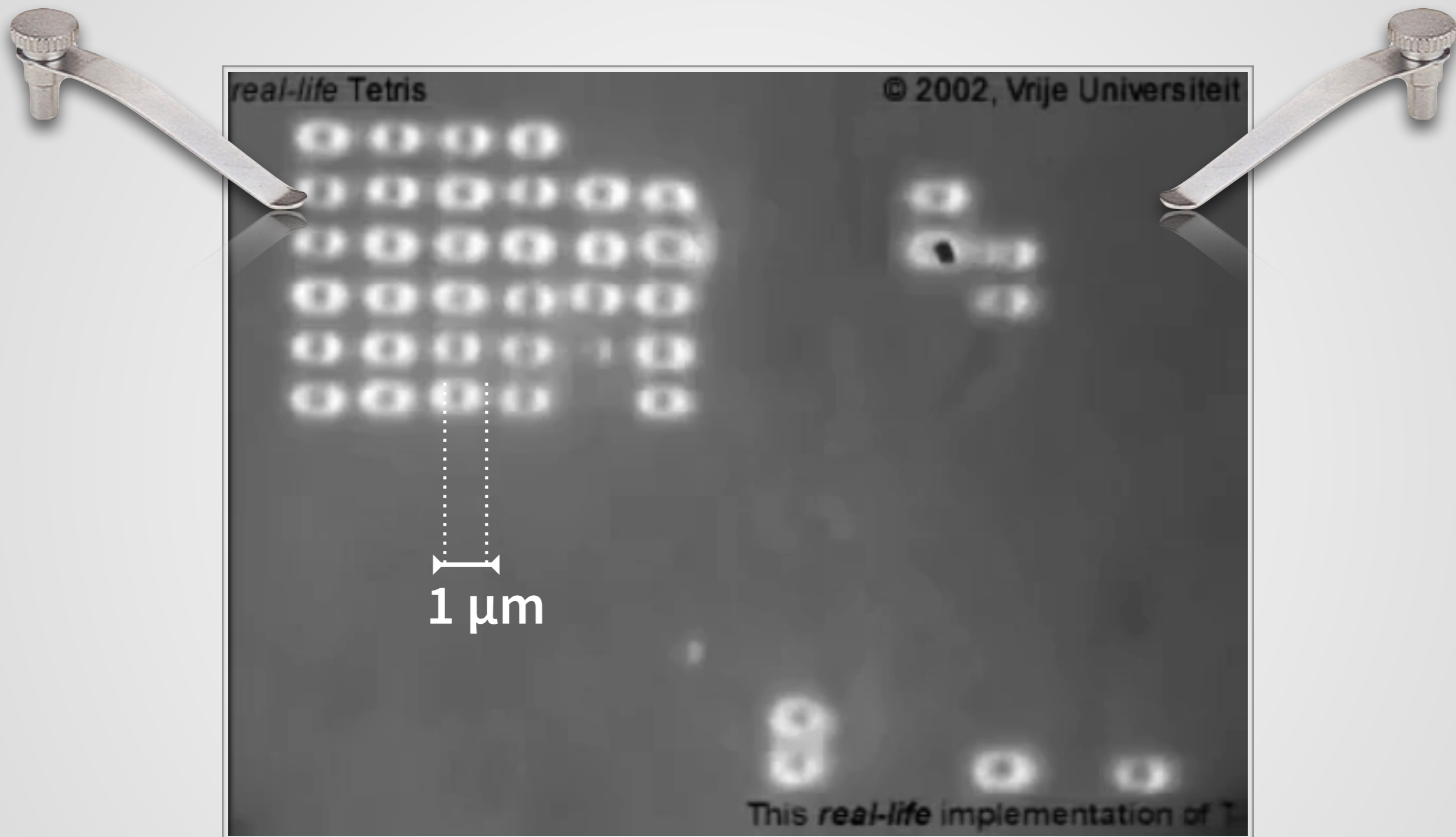
Columbia (BA), Cornell (PhD, 1952)

AT&T Bell Labs, USA (1952 to 1991)

*microwaves, nonlinear optics,  
and laser trapping*



<http://www.osa.org/history/biographies/arthur-ashkin/>



[https://youtu.be/jCdnBmQZ6\\_s](https://youtu.be/jCdnBmQZ6_s)

**"for groundbreaking inventions in the field of laser physics"**

with one half to

**Arthur Ashkin**

Bell Laboratories, USA

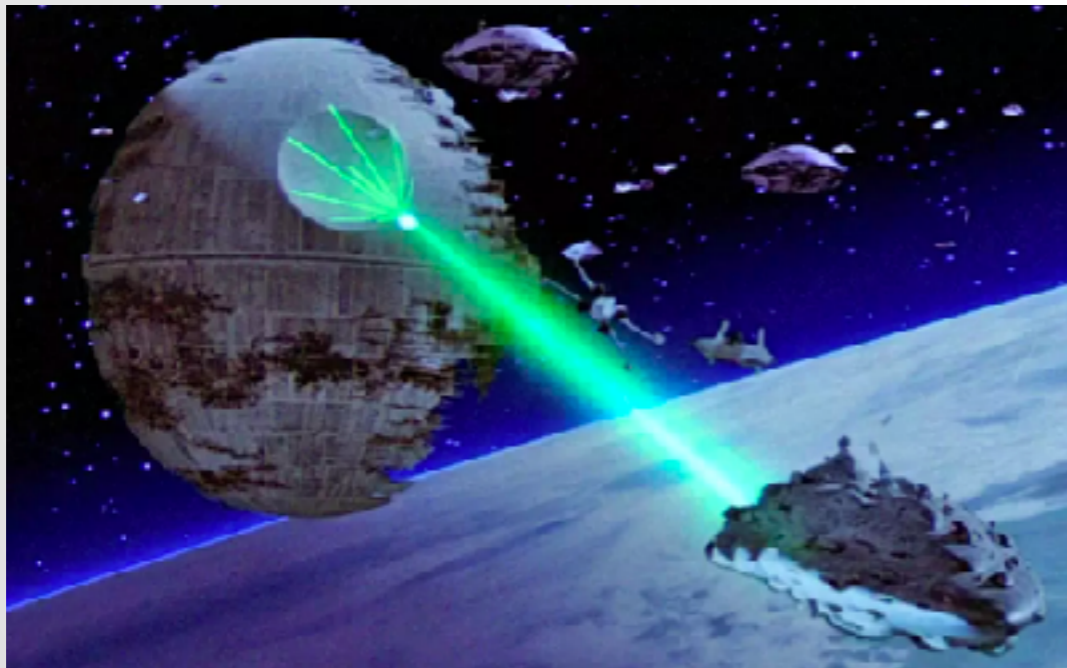
**"for the optical tweezers and their application to biological systems"**

The inventions being honoured this year have *revolutionised laser physics*. Extremely small objects and incredibly rapid processes are now being seen in a new light. Advanced precision instruments are *opening up unexplored areas of research* and a multitude of *industrial and medical applications*.

Arthur Ashkin invented optical tweezers that *grab particles, atoms, viruses and other living cells with their laser beam fingers*. This new tool allowed Ashkin to ***realise an old dream of science fiction*** – using the radiation pressure of light to move physical objects. He succeeded in getting laser light to push small particles towards the centre of the beam and to hold them there. Optical tweezers had been invented. A major breakthrough came in 1987, when Ashkin used the tweezers to *capture living bacteria without harming them*. He immediately began studying biological systems and optical tweezers are now widely used to investigate the machinery of life.

**<https://old.nobelprize.org/phy-sci.pdf>**

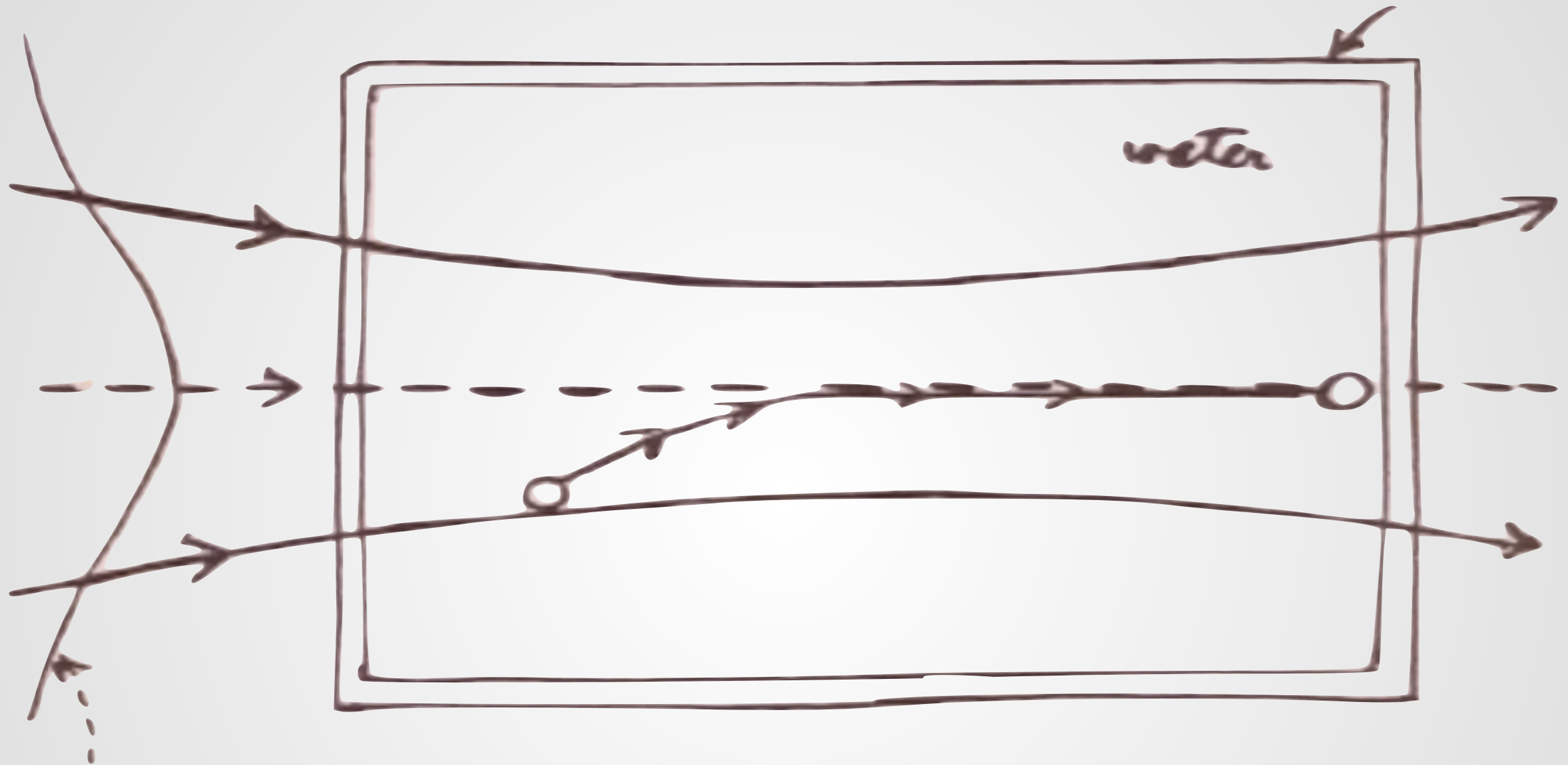
# SCIENCE FICTION FROM THE 1980s



NEED



LASERS



"What kind of force is that?  
-That's a new kind of force!"

# Observation of a single-beam gradient force optical trap for dielectric particles

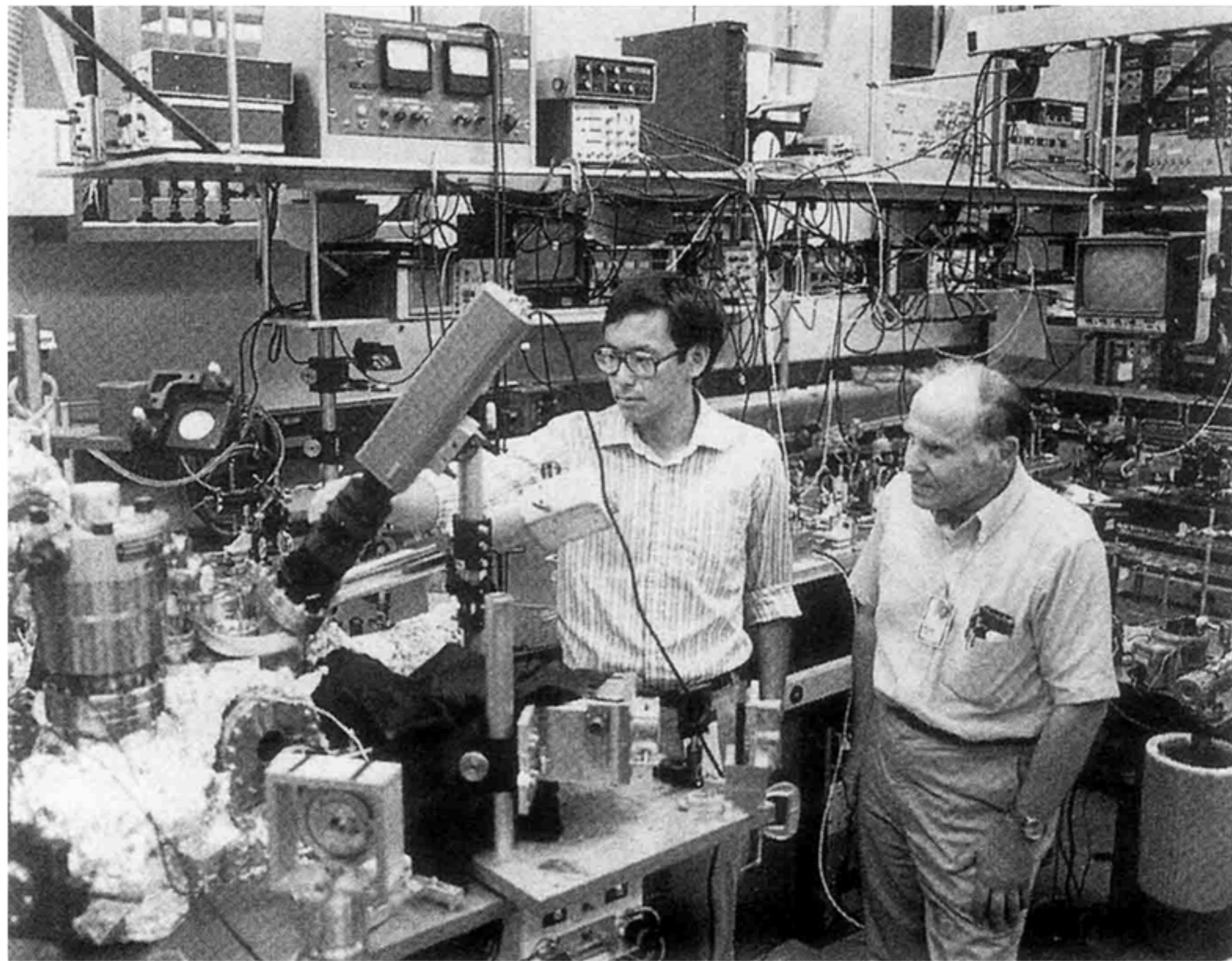
A. Ashkin, J. M. Dziedzic, J. E. Bjorkholm, and Steven Chu

*AT&T Bell Laboratories, Holmdel, New Jersey 07733*

Received December 23, 1985; accepted March 4, 1986

Optical trapping of dielectric particles by a single-beam gradient force trap was demonstrated for the first reported time. This confirms the concept of negative light pressure due to the gradient force. Trapping was observed over the entire range of particle size from 10  $\mu\text{m}$  to  $\sim 25$  nm in water. Use of the new trap extends the size range of macroscopic particles accessible to optical trapping and manipulation well into the Rayleigh size regime. Application of this trapping principle to atom trapping is considered.





# LIGHT PRESSURE

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Comet Lovejoy from orbit  
– NASA

[wikipedia.org/wiki/Comet\\_tail](https://en.wikipedia.org/wiki/Comet_tail)

Force  $\sim 1\text{nN}$  per W



“

Provide ships or sails  
adapted to the  
heavenly breezes,  
and there will be  
some who will brave  
even that void ”

”

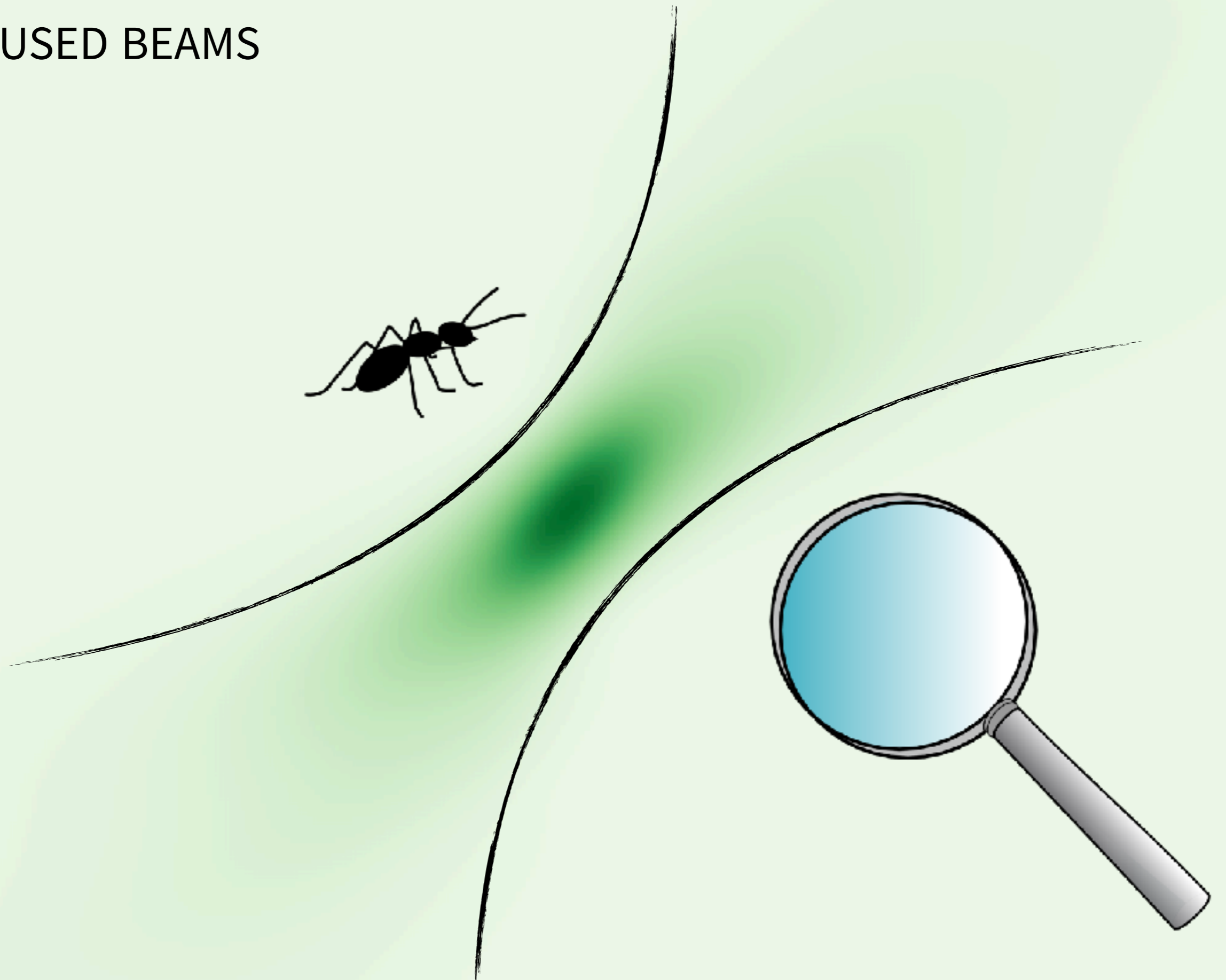


[https://en.wikipedia.org/wiki/Solar\\_sail](https://en.wikipedia.org/wiki/Solar_sail)

# GRADIENT FORCE



# FOCUSED BEAMS



## GRADIENT FORCE

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- ▶ Small object

$$U = -\mathbf{p} \cdot \mathbf{E}$$

- ▶ Large object

*bending of rays*



## FURTHER DEVELOPMENTS

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- ▶ multiplexing, e.g with spatial light modulators
- ▶ angular momentum
- ▶ applications in biology
- ▶ atoms, Bose-Einstein condensates
- ▶ sound waves
- ▶ ***many more...***

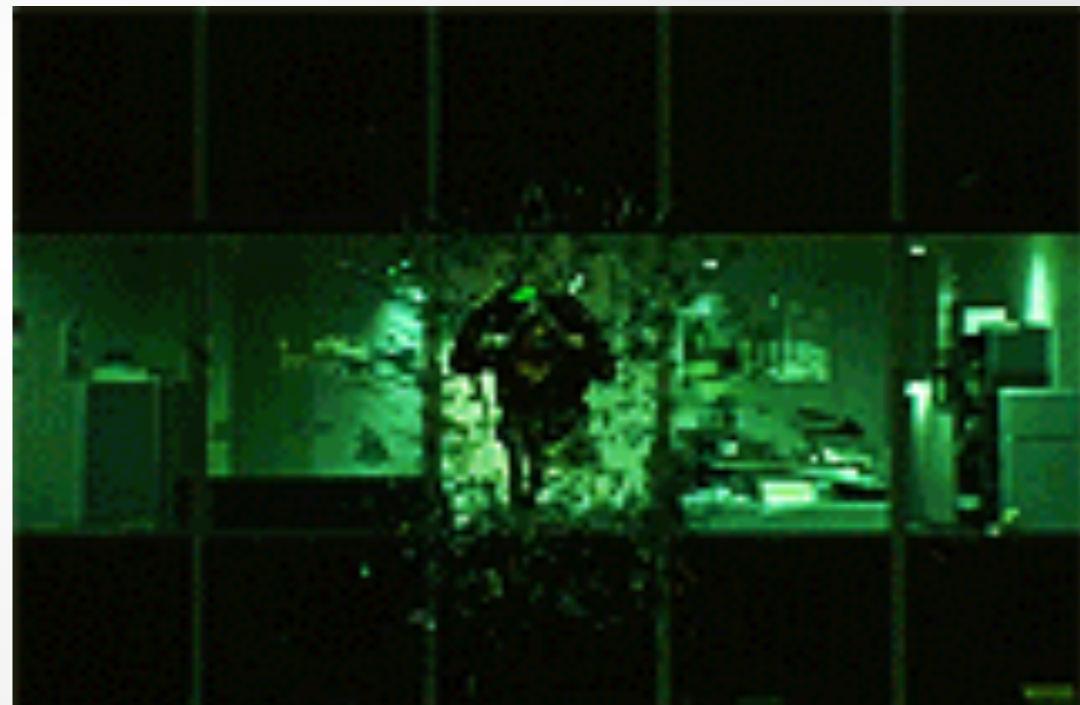






# OPTICAL EARNSHAW THEOREM: $\nabla \cdot \mathbf{F}_s = 0$

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## GRADIENT FORCE

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- ▶ Small object

$$U = -\mathbf{p} \cdot \mathbf{E}$$

- ▶ Large object

*bending of rays*

