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Astrophysical Masers
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What is a maser?

- Gas is heated causing particle excitation
- Excited molecules are funneled into a resonant cavity
- The spontaneously emitted photons cause stimulated emission from excited molecules
- Excited photons reflected inside a chamber
- Gain exponentially related to resonant cavity length
Optical Amplifiers

- Optical input signal
- Fiber-to-amplifier couplers
- Active medium
- Pump source
- Amplified optical output
Astrophysical Maser

- There is no resonance cavity
- The radiation enters from a source (star, black hole, etc.) and travels through the gain medium in one pass
- The particles in the lower energy levels are excited though quickly drop to the lower energy level, emitting radiation at the same frequency
Length vs. Gain
Methanol Maser
Star Formation

- Masers mark the formation of young stars
- As the star begins to spin bipolar outflow occurs
- Circumstellar Disk
  - H₂O and OH
- Shock Front
Water Maser

- Can put out as much or greater energy as the Sun – all at single spectral line!
Megamasers

- Most powerful are water masers
- Size of or greater than Solar System
- Accretion disk around black hole
- Masers from center and edges
  - Allow size and rotation to be measured
- Dates existence of water to much earlier than predicted

An artist’s impression of an accretion disk surrounding a super-massive black hole. Masers appear in the disk in front of the black hole as well as along a line where the disk is moving directly toward or away from us. This results in a characteristic triple-peaked signature as seen in the lower part of the figure.
Dasars

- Formaldehyde de-excited by collisions
- Absorbs background radiation
- Darkness Amplification by Stimulated Absorption of Radiation
Uses

- Masers reveal the composition of certain regions of space
- They can be used to date the existence of certain molecules
- Masers exist in specific environments, many of which were theorized not to exist naturally
- Reveal certain areas invisible to regular telescopes such as galactic centers

- OH
- CH
- H$_2$CO
- H$_2$O
- NH$_3$
- CH$_3$OH
- SiS
- HC$_3$N
- SiO
- HCN
- H
Masers were created over 50 years ago and were thought not to be a natural occurrence.

Astrophysical masers discovered two years after first artificial.

Astrophysical maser is a region of gas which amplifies microwave radiation through stimulated emission.

Tell us of the environments in different areas of space, from young stars, to comets, to super-massive black holes.

Allow us to date the existence of certain molecules.

Allow the measurement of distances to other galaxies as well as their speed and acceleration.
Sources

- *Fundamentals of Photonics*,


- *Masers*, Jerome R. Singer, 1959

- Interstellar hydroxyl and water masers and formaldehyde masers and dasars, D ter Haar and Margaret A. Pelling