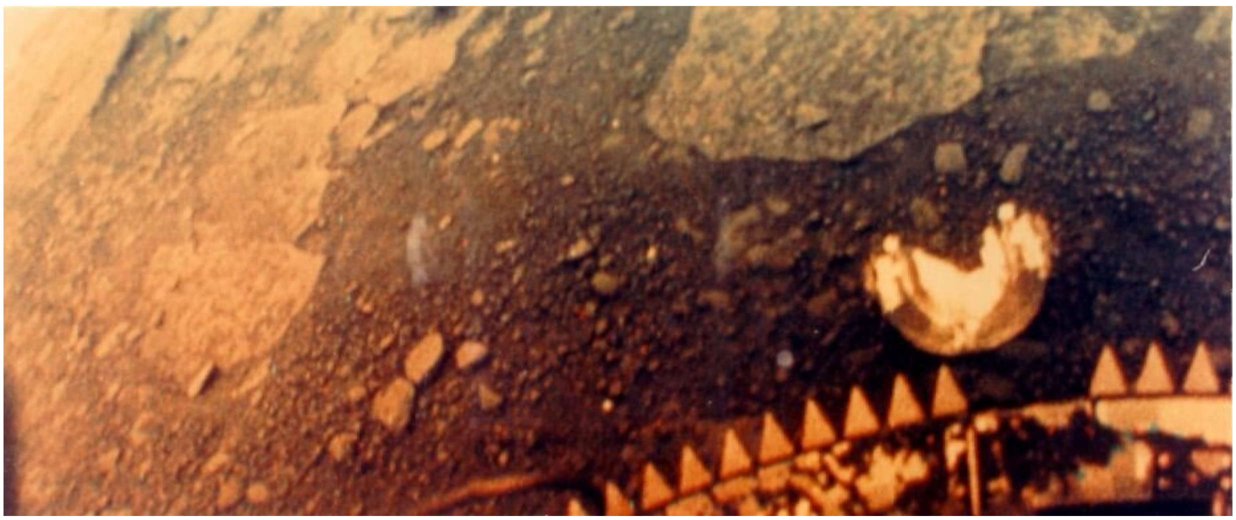
Scientists look at feasibility of power beaming through the Venus atmosphere

July 10 2023, by Evan Gough



The first color pictures taken of the surface of Venus by the Venera-13 space probe. The Venera 13 probe lasted only 127 minutes before succumbing to Venus's extreme surface environment. Part of building a longer-lasting Venus lander is figuring out how to power it. Credit: NASA

A few weeks ago, a team of scientists from Caltech announced that they had successfully transmitted energy from an orbiting satellite down to Earth. It wasn't a lot of energy, but it showed that it was possible.

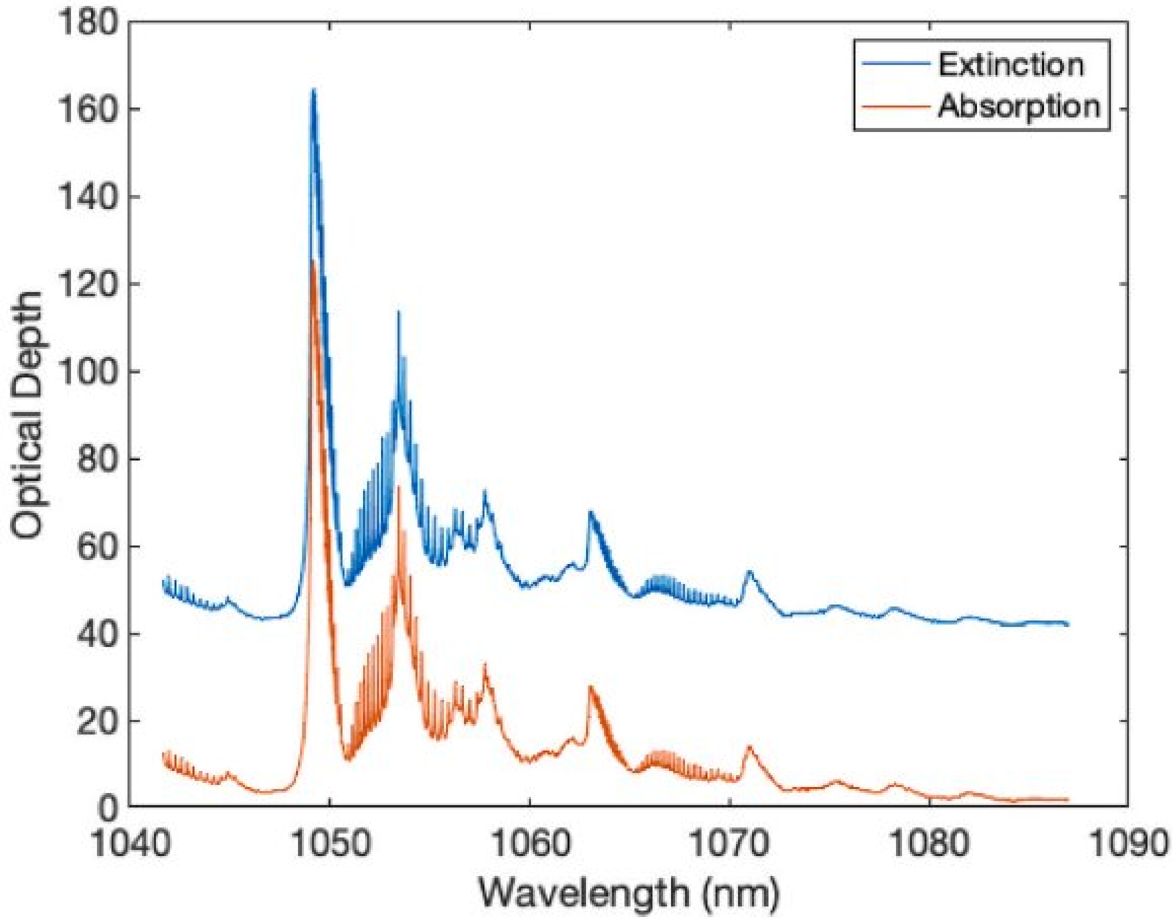
Eventually, we might be able to beam energy from solar satellites down to Earth, making solar energy available almost anywhere and helping combat climate change. But there's another potential use: powering surface probes on Venus.

Everybody knows about Venus. It's killed multiple landers with its extreme heat and crushing atmospheric pressure. The old Soviet Union sent a series of probes to the planet's surface, and most of them failed. The most successful one was Venera 13, which survived for just over two hours at 457 °C (855 °F), and was subjected to 9.0 MPa (89 standard atmospheres) of pressure.

Despite Venera 13's brief but significant success, the planet held onto its secrets, and we're drawn back to its surface to reveal them. That's why NASA wants to send a lander to the surface as part of its DAVINCI+ mission (Deep Atmosphere Venus Investigation of Noble gases, Chemistry, and Imaging.)

But there's the question of how to power a lander on Venus' unique, treacherous surface, assuming we can build one that won't easily succumb to Venus' nasty conditions. The usual methods—solar power, batteries, radioisotope thermoelectric generators—aren't up to the task. That's according to new research titled, "Feasibility of power beaming through the Venus Atmosphere," published in the journal *Acta Astronautica*. The corresponding author is Erik Brandon from the Jet Propulsion Laboratory.

"State-of-the-art space power technologies comprising solar arrays, batteries and radioisotope thermoelectric generators are not capable of operating on the surface of Venus, limited by the high temperatures, high pressures and corrosive environment," the authors explain.



This figure from the study shows how Venus' atmosphere makes it difficult to beam power from above the clouds to the surface in microwaves. "In this spectral range, water vapour and CO2 are the only significant absorbing gases, while H2SO4 clouds/aerosols are the primary contributors to the extinction optical depths," the paper explains. Credit: Grandidier et al. 2023

Venus is closer to the sun, but its thick atmosphere means not much solar radiation reaches the surface. About 75% of the sun's energy is reflected by Venus' clouds, and only about 2.5% of the solar flux incident at the top of the atmosphere reaches the surface. Up above the clouds, solar energy is abundant. Venus receives twice as much solar irradiance at the top of its atmosphere as Earth does at the top of its atmosphere.

Could this abundant energy be harnessed by solar collectors above the clouds and then beamed down to a lander/rover? It would have to make it through a lot of thick clouds. "The feasibility of such an approach and other related mission concepts are discussed herein from a perspective of atmospheric absorption and scattering of the beamed energy," the paper states.

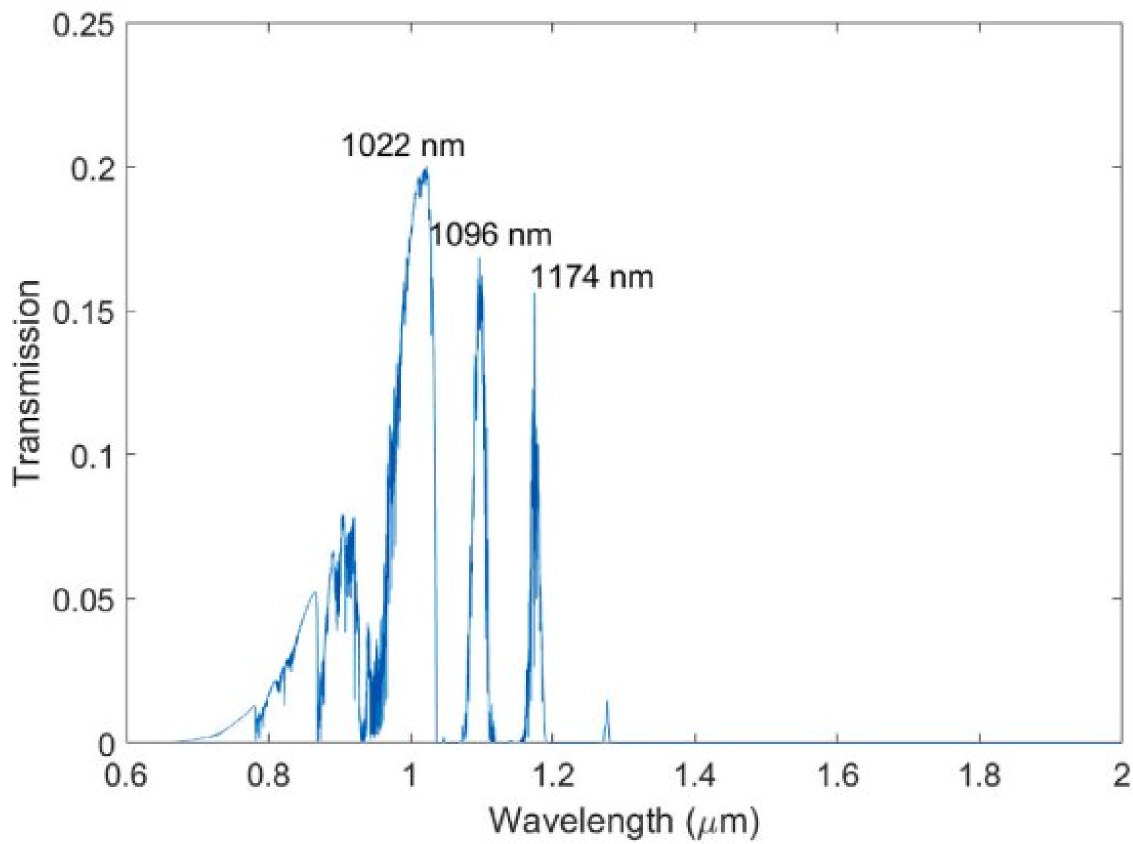
Beaming energy from one place to another is called wireless energy (or power) transfer. There are two types: near-field and far-field. Near-field is short-distance energy transfer like the type used in charging pads for mobile devices. Far-field energy transfer is also called power beaming, and it uses microwaves or lasers to beam the power from a producer to a receiver.

One problem with beaming energy from an orbital solar collector to a surface vehicle is the complications in a Venus geostationary orbit. The planet rotates so slowly that the geostationary orbit is at a great distance from the planet, making the orbit unstable. Somehow, a solar collector would need to be closer to the planet. Above the upper clouds, at about 60 or 70 km altitude, a collector would essentially receive all available sunlight. Mission design might have to keep the collector, or group of collectors, at the right altitude and position.

An alternate solution is to beam a portion of energy to a lander on each orbit, which could be enough. "Hundreds of Wh (Watt hours) of energy could be received over the course of several orbital passes of the lander," the authors explain.

But those are larger issues of overall mission architecture. This research assumes that there are solutions to that problem. In this work, the authors focus on how to beam the energy and receive it, something that hasn't been studied thoroughly. "However, to date, there has not been a thorough study regarding the feasibility of transmitting power at relevant wavelengths, if a suitable platform and mission architecture could be devised and implemented," the authors write.

The problem is that Venus' atmosphere is dense and contains chemicals that interfere with power beaming by microwaves. CO_2 concentrations are a particular problem.



This figure from the study shows energy transmission by laser at different wavelengths from an altitude of 47 km. The 47 km altitude was chosen because, below it, there's less scattering of the beamed energy. There are likely enough windows in the atmosphere to allow lasers to transmit enough energy to operate a surface lander. Credit: Grandidier et al. 2023

Lasers might be a better option. Even though there are problems with the dense atmosphere, there are certain "frequency windows" in the atmosphere that could allow power-beaming with lasers. "Counterintuitively, power beaming via laser sources may be possible at Venus despite the continuous cloud coverage, given certain optical/infrared 'windows' present within the Venus atmosphere, which are not available using microwave power beaming," the authors write.

Lasers have other advantages, too, like reduced beam spreading compared to microwaves. That means receiving antennae don't need to be as large. A one-meter receiver might be enough and wouldn't be so unwieldy as to interfere with the design of a lander too much.

While solar energy is abundant at the top of Venus' atmosphere, beaming it down through the entire atmosphere might not be the best approach. Instead, a balloon or some other vehicle could situate itself near the middle of the atmosphere. There it would receive enough solar energy to be feasible, and would only need to beam the energy through a portion of the atmosphere.

The research shows that the 47 km altitude is significant. There's a cloud base at that altitude, and below it, the beamed energy is subject to less scattering. It also shows that from 47 km, the highest transmission factor is at 1022 nanometers, where about 20% of the beamed energy would reach a surface lander.

"These calculations point to a plausible approach for power beaming at Venus, using transmission from an aerial platform operating near the cloud base," the authors write.

But does the technology to do this exist? The paper doesn't discuss what type of vehicle or platform could be used at 47km altitude. They focus on the power beaming itself, and if calculations show that it's possible.

But they also talk about available laser technology and if it's up to the task.

A prototype aerial robotic balloon, or aerobot, is readied for a sunrise test flight at Black Rock Desert, Nevada, in July 2022, by team members from JPL and Near Space Corporation. The aerobot successfully completed two flights, demonstrating controlled altitude flight. Credit: NASA/JPL-Caltech

According to the researchers, we don't quite have the right kind of laser yet.

Researchers are busy developing them, though. Ytterbium-doped fiber lasers (YDFLs) that work in the near-infrared (NIR) window that can also operate at high power are under development. Unfortunately, they don't operate at the ideal wavelength for use at Venus: 1022. Instead, they're limited to two other ranges: 970–980 nm and 1030–1100 nm. But lasers are an intense focus of different researchers around the world, and progress is steady.

The task of keeping some kind of aerial platform steady and in the correct position is critical to any power-beaming mission. But researchers are already working on balloons and other aerial platforms for use on Venus. Assuming they can be developed, the authors are confident that a power-beaming scenario can rise to the challenge and create successful missions to the Venusian surface.

"Also, although there are engineering and mission design challenges regarding control and pointing of such an aerial vehicle platform used for power beaming and in overall thermal management, this analysis shows that these optical windows could be exploited to enable sufficient mission-enabling power levels to be beamed to the surface of Venus."

We need a better understanding of Venus' atmosphere before a specific system can be designed. DAVINCI+ has three main scientific objectives, and one of them is to understand the atmosphere as it travels through it.

Its findings will help scientists understand what obstacles they face in beaming power to the planet's surface. If it can be done reliably, then Venus will be open to exploration.

More information: Jonathan Grandidier et al, Feasibility of power beaming through the Venus atmosphere, *Acta Astronautica* (2023). DOI: 10.1016/j.actaastro.2023.06.042

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