Integrated nonimaging optical design for evacuated tube solar thermal collector

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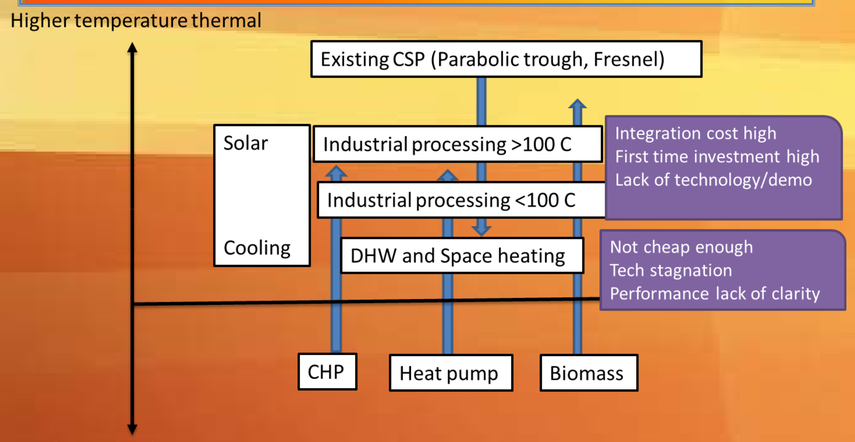
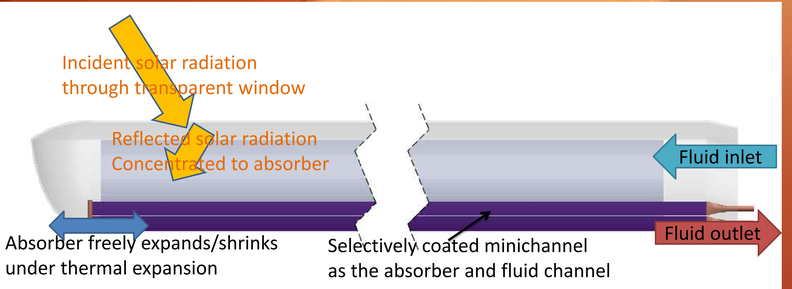
Background and the problem

Solar thermal market is experiencing a stagnation for lower temperature domestic hot water applications worldwide. This is due to the two leading zones, the Chinese market(60%) and European countries(lead by Germany), are seeing over production. China is seeing a meager 3% increase in production compared to 15% same quarter from last year. However, the medium temperature solar products, and solar engineering are seeing significant increase this year. The Chinese solar thermal engineering market has grown 30% this year; the North American solar projects are also receiving more stimuli such as rebates. The current solar thermal products still remain polymer pool heater, flat plate collector and all glass evacuated tubes. These are not technologies suited for higher temperature. The high temperature CSP technology is also having a difficult time sizing down to be used for medium temperature applications due to its complexity in tracking.



Working principle

The collector is positioned with its axis along east-west. The glass tube is shaped with a cross section of a nonimaging concentrator designed for 34 degrees half acceptance angle to accommodate the seasonal change of the sun. The incident solar radiation passes through the transparent upper part of the glass tube. Then it is concentrated by the lower part of the tube which is coated with reflective material and concentrates onto the absorber. As the working fluid (Duratherm 600) passes through the minichannel absorber, or across the surface of the heat pipe condenser, it heats up and carries away the thermal power generated by the device. The tube is evacuated and therefore very small amount of conduction or convection heat loss exists. The radiation loss is kept low by selective coating and relatively smaller absorber area due to concentration.



Challenges and solutions

❑ **Affordable/cost effective**

The general industrial payback time for implementing alternative energy sources tend to be 1 to 2 years. Using solar to compete with other energy sources within such a short time frame is sometimes prohibitive because solar collector investment is typically its system life time, which ranges from 20 to 30 years.

- Evacuated tubes are a proven mature technology that has 3 years payback time without subsidies, which resulted in their large scale implementation and mass production.

❑ **Efficient at higher temperatures**

As the working temperature rises for the solar thermal collector, the efficiency drops. Maintaining the efficiency above 40% despite of the higher working temperature is necessary for solar thermal to be comparable with other forms of energy.

- Although without tracking, the nonimaging wide angle concentration ratio is still able to achieve 1.1 to 1.8 as well as utilizing both the front and back of the absorber. Therefore 40% efficiency at 250 Celsius is achievable with the current prototype of the device.

❑ **Easy to install and maintain**

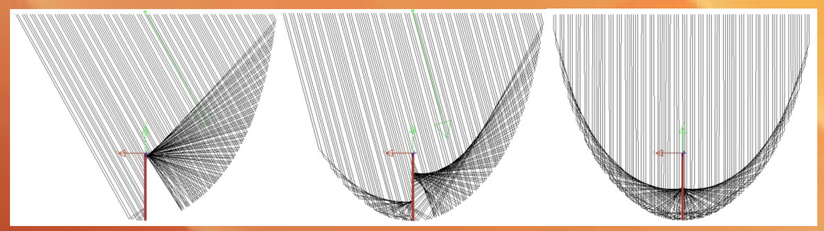
Many technologies (LFC, PTR), originally designed for higher (>300 Celsius) applications such as driving steam turbine to produce electricity, have been sized down to be optimized for the medium temperature application. All of them require tracking which means higher cost of installation and maintenance.

- Non-tracking device installation is well established in the market and almost as simple as plug and play. No poles have to be put down, therefore rooftop installation is also possible with a small amount of labor. Without any moving parts except pumps and fluids, the maintenance is also low.

❑ **Durable**

Many solar thermal devices which utilize concentrators face the problem of degradation of the reflective layer over time.

- The vacuum inside of the evacuated tube collectors have been proven to last more than 25 years, the reflective coating for the design is encapsulated in the vacuum inside of the tube, which will not degrade until the vacuum is lost.



Ray tracing according to different seasonal sun position

3.6 square meters prototype array

- ❑ **Each tube is 1.87 meter X 87mm aperture area**
- ❑ **Thermal imaging shows gas getter area to be significantly hotter**
- ❑ **Heat pipe design**
- ❑ **Reflective coating on the outside with protection**
- ❑ **Chose Alanod Sunselect as the absorber**
- ❑ **Initial testing shows around 50% efficiency at 180 Celsius**