Title:

Motion-Free Tracking Solar Concentrator for Fiberoptic Daylighting

Applicant:

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Partners:

Doyon, Ltd., Fairbanks
Cold Climate Housing Reseach Center, Fairbanks

Cost:

$458,000

Previous applications:

N/A

1. **Project Summary**

a) **Project Description**

Goldstream Solar proposes to develop a motion-free solar tracking panel so that natural daylight can be piped to the interior of buildings via fiber optics.

Interior space requires illumination, and natural light is universally preferred to artificial light. Artificial lighting is typically powered by electricity derived from fossil fuel, and many communities in Alaska have some of the highest electricity fee schedules in the nation. Photovoltaic panels are less than 20% efficient and further conversion penalties are paid to turn the electricity back into light. For illumination purposes, it is far more efficient to simply channel the sunlight indoors. Windows and skylights are common, but the relatively low R value for glazing increases the winter heat loss for the building when the sun is down or behind clouds. Furthermore, it is structurally difficult to add windows or skylights to existing buildings. One alternative is to concentrate the sunlight down to a much smaller area using a Fresnel lens and then pipe the sunlight into the building via a small roof or wall penetration. A small penetration means a small change in the heat load, and simplifies installation on an existing building. Furthermore, the light pipe can extend into basements and other windowless rooms for which adding a window or skylight is impossible. This technique is called fiber optic daylighting.

Because the sun is in constant motion, the location of the focused sunlight changes unless the focusing lens is also moved. Typically, the target and the lens are mounted together on a pedestal and swiveled north/south and east/west with motors. The pedestal must allow the lens/target assembly full range of motion while resisting the effects of wind. These restrictions mean that the components must be heavily built, adding to the cost of the system and making it difficult to install on an existing roof.

The aim of our technology is to turn fiber optic daylighting into a cost-effective green tech alternative that is as viable in rural Alaska as it is in urban Alaska by removing motion from the system. We actively and controllably steer the sunlight onto the end of the light pipe using liquid crystal material in thin, stationary steering panels, which eliminates the need for heavy and expensive motor-driven machinery. The light weight, low maintenance and small building penetration of our system particularly lend themselves to retrofit installations on the roof or south-facing wall of buildings not designed for a substantial increase in weight load (Fig. 1). Increasing the amount of natural light in Alaskan homes, offices, and businesses will reduce the consumption of expensive, fossil-fuel-generated electricity in the cities and villages alike without increasing the winter heat load on the building.

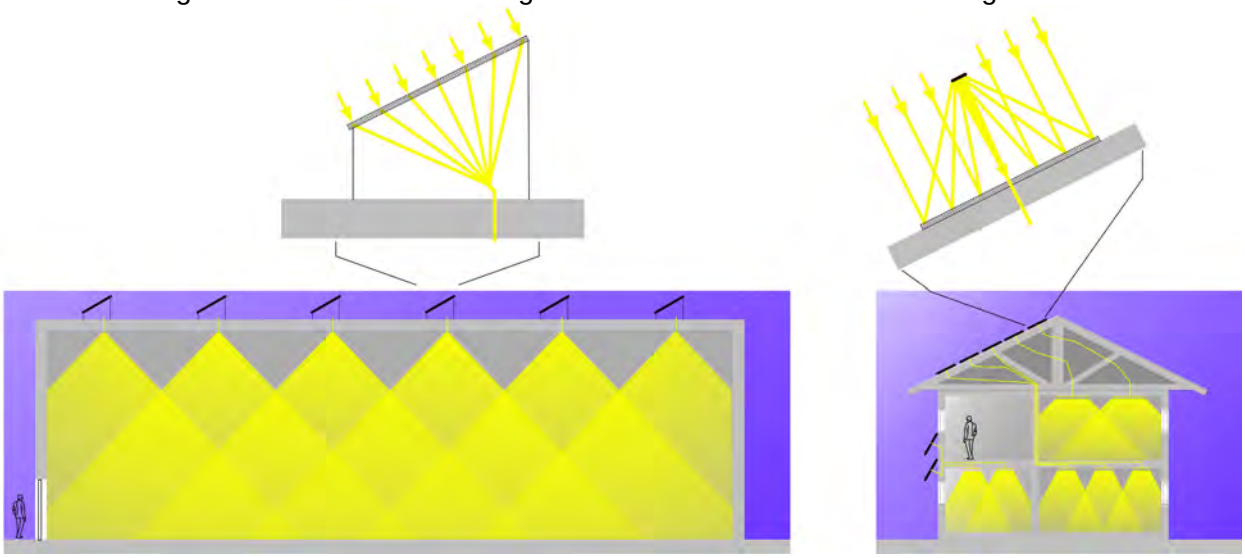

Figure 1

b) **Project Eligibility**

The goal of our project is to improve fiber optic daylighting technology by completely re-engineering the process of tracking the sun. This satisfies criterion 2 of AEA-12-047 section 4.2. We completed a

Phase I SBIR award from the National Science foundation in 2010. The funding allowed us to develop lab-scale prototypes for proof of concept, which puts us at Technology Readiness Level TRL 4. We have posted video of several of these prototypes and other information at www.goldstreamsolar.com/SolarConcentrator/SCHome.html

c) **Project Innovation**

A simple prism suspended in air that is made from a transparent material such as glass will refract light incident from above, Fig. 2(a). If the prism's refractive index can be continuously varied, Fig. 2(b), there is a range of incident angles for which the light can be made to emerge from the prism in some chosen direction (straight down in this case) by adjusting the prism's refractive index. This can be done with a prism made from a liquid crystal and controlled by a low-voltage signal.

Figure 2

In our system, shown schematically in Fig. 3, a thin transparent film is manufactured with a series of parallel, triangular grooves on one face. These grooves are filled with liquid crystal (LC) to form an array of uniform LC prisms. A modest voltage is applied between a pair of transparent conducting surfaces enveloping the LC layer, resulting in a device that will direct sunlight from a range of incident angles to the direction of choice. Two steering layers with crossed LC directionality and parallel grooves are stacked together to form a steering panel that steers 100% of the incident sunlight in the direction of choice. Adding focusing elements such as lenses will keep solar radiation focused on a target over a range of incident solar angles.

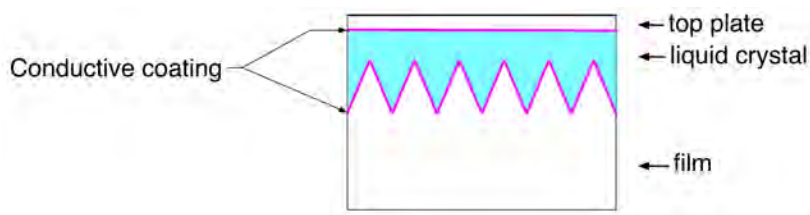

Figure 3

d) **Priority**

1) John Pender is originally from Fort Yukon, born 1958 in the Alaska Territory, lifelong Alaska resident and owner of Goldstream Solar, an Alaska business.

2) Deployment of concentrated solar power technology is most suited to locations with low cloud cover. This is the case over most of Interior Alaska. Furthermore, Fairbanks and the Interior Alaska villages face some of the highest energy costs in the State of Alaska. A system for reducing electricity consumption for interior lighting that can be installed on existing structures would lower the cost of living in Interior Alaska.

2. **Technology Validation and Research Methodology**

a) **Objectives**

1) Steering Panel Efficiency

1a) Transparent electrodes. The LC display standard for the transparent conductor is indium tin oxide (ITO), which we have use to construct many functional prototypes (see, for example www.goldstreamsolar.com/SolarConcentrator/PrototypeFrames/Prototype4.html). ITO has a refractive index (RI ~ 2) that is much higher than that of the other materials in the steering panel (RI ~ 1.5). This means there are unacceptable reflection losses every time light enters or exits an ITO layer. We propose using a mesh of carbon nanotubes (CNT) for the conduction layer whose RI can be matched to that of all other device materials, eliminating the reflection losses. We have demonstrated that CNT coatings work well as applied to the planar surface above the liquid crystal. However, application to the prism surface degrades the optical qualities, so a different application method is required.

1b) Engineered liquid crystals (LC). Commercial LC material is optimized for displays. The characteristics we require are different in part because of weather exposure for the steering panel. We will work with our commercial vendor, EMD Chemicals, to design and optimize a custom LC blend.

1c) Assemble prototypes. Build up to 100 small-scale prototypes for initial environmental testing.

2) Secondary optical elements. The second objective is to develop a computer model and design an optical system for extending the working time for the tracker by incorporating secondary optical elements (SOEs). A tracking concentrator with a steering range of ±27° corresponds to almost 4 hours of active steering per day. This range can be nearly doubled by including SOEs as shown in Fig. 4.

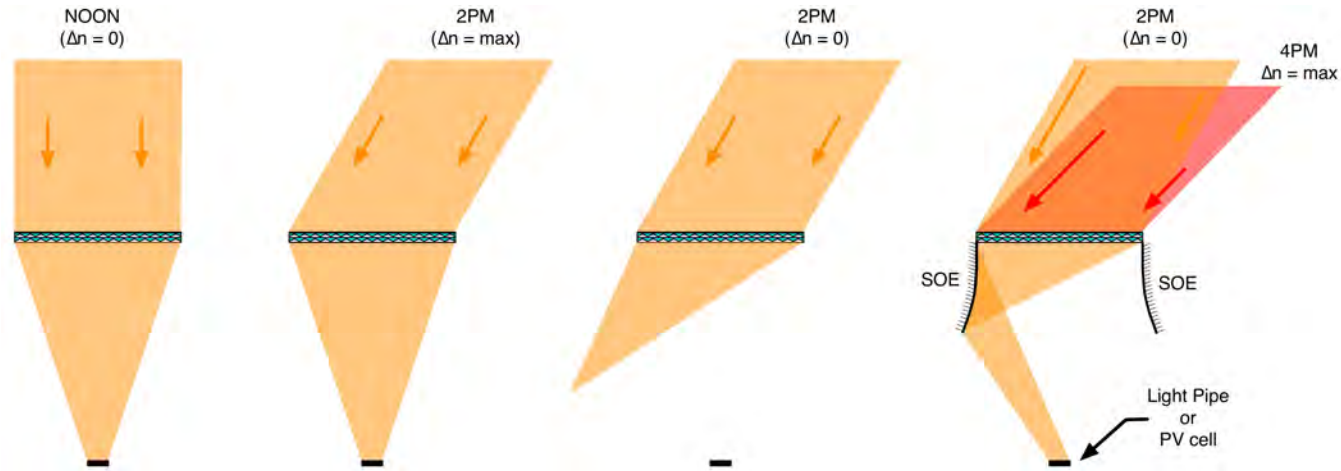

Figure 4

b) **Methodology**

We propose to make the prismatic surface both transparent and conducting in a completely novel way. The acrylic film will be first coated with a CNT coating (an inexpensive and reliable process for planar surfaces) and then a die will emboss the prism structure onto the film through the CNT coating.

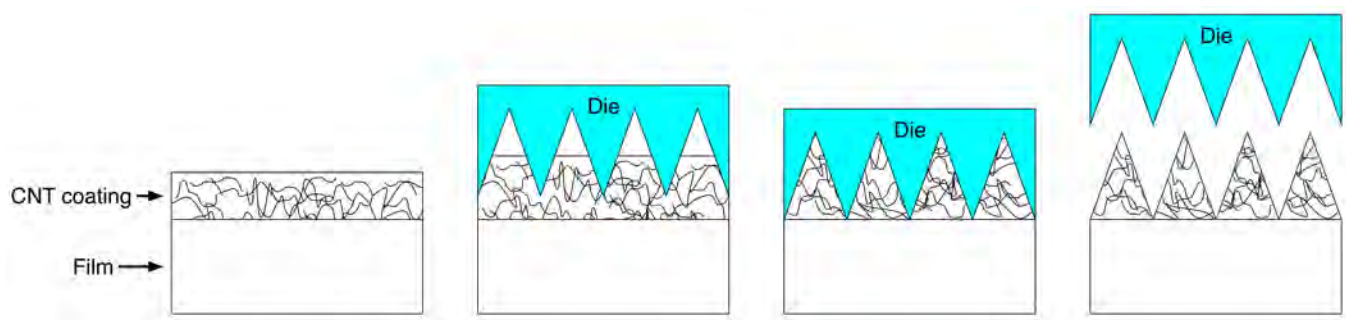

Figure 5

The design work for the SOEs will be done using Mathematica and Rayica software.

3. **Summary or Project Schedule and Summary of Project Budget**

Object-ive	Task	Duration (months)*	Est. Material Cost ($000s)	Est. Labor (person-months)	Est. Labor Budget ($000s)	Misc. costs/ Travel	Total ($000s)
1a	Demonstrate embossing of CNT onto acrylic with stock die	3	21	2	27.9	10.0	58.9
	Make custom embossing die	3	60	1.5	20.9		80.9
	Make prototype run of electrode material (250 m^2)	1	32	3	41.8		73.8
1b	Engineer custom LC mixture	3	14	4	55.8	5.0	74.8
1c	Prototype build	1	2	3.5	48.8		50.8
2	Secondary Optical Element Design	2	0	1.5	20.9		20.9

	Secondary Optical Element Fabrication	1	14	1	13.9	5.0	32.9
	Prototype build with SOE	1	16	3.5	48.8		64.8
TOTAL							**$458**

*Total project duration is estimated to be 1 year. Many tasks can be completed concurrently

4. **Project Team Qualifications**

The team consists of technical professionals including Dr. John Pender, the principal scientist/investigator and the inventor, Brad Cantos, a senior personnel for engineering and manufacturing, Eric Pan, a senior personnel for project management. Additionally, Dr. Vassili Sergan and Dr. Tatiana Sergan of California State University, Sacramento, are senior consultants for liquid crystal material and processing. All team members have extensive experience in start-ups and commercialization of technology products. The team is also supported by a group of advisors in the green building, fenestration and fiberoptic lighting industries for assisting commercialization of the proposed innovation. One of our advisors in financing and business development is Mr. Todd Fearon, President of Boyett Construction, who has over 25 years of experience in construction of commercial and residential buildings and real estate development.

5. **Discussion of Commercialization of Funded Technology**

We aim to achieve a net profit of at least about $1.5 million on sales of at least $8.7 million or 207,000 SF rooftop installation (part only excluding installation) by year five. It means creation of about 50 jobs (total from our business, outsourcing manufacturing partners, and distributors) for about 17 projects of typically 50K SF buildings with 24% panel-to-rooftop area ratio. Hence, we set out the following annual objectives:

Year 0: Complete working prototypes of at least 6 inch x 6 inch and up to 20 inch x 20 inch motion-free sun tracking panel unit as well as light distribution and lighting control accessories.

Year 1: Identify at least ten early adopters for product specifications; they shall include at least one each of supermarket, hospital, education, office, lodging, warehouse, and big box retail.

Year 2: Negotiate and plan site installation with early adopters. Identify regional specialty distributors in Alaska, Northern California, Southern California, Arizona, Nevada, Utah, and New Mexico.

Year 3: Build pilot line and ramp up production. Begin early adopter site installation. Achieve close-to-breakeven through lowering operation cost by outsourcing and income generation through sales.

Year 4: Begin UL, LEED, and other relevant product certifications. Conduct training and certify regional specialty distributors including parts and installation services. Complete marketing and communications materials and distribution.

Year 5: Achieve net income of about $1.5 million on revenue of $8.7 million. May license out (technology transfer) and qualify manufacturing lines. Expand sales channels.

Commercialization strategy

Our commercialization strategy includes the development of key strategic partnerships with manufacturers associated with production process development and production line of motion-free sun tracking panel through licensing agreements as well as qualified regional marketing partners (i.e. specialty distributors including installation services) through sales channel agreements. Our strategy also includes joint ventures or alliances with synergistic companies to jointly develop light distribution and lighting control products to offer complete daylighting solutions to customers. We will engage early adopters, some of whom could be our corporate strategic alliance partners, for system integration, system optimization, field demonstration, weatherization durability, and financing. The outcome of early adopter program is to deliver prototype products for UL and other applicable certifications prior to market introduction.