

Rapid Vitamin D Enhancement in Mushrooms Using Pulsed UV Light

51st Annual Penn State Mushroom Industry Conference
Sept 20-22, 2009



Lou Panico, CEO

Presentation Overview

- **The Nutritional Value of Vitamin D**
- **Mushroom Vitamin D Research**
- **Understanding Pulsed UV Light**
- **Future Pulsed Light Advances**
- **Acknowledgements**

Vitamin D – the “Nutrient of the Decade?”

- Vitamin D, known as the “**sunshine vitamin**”
- Vitamin D has been found to:
 - Strengthen bones
 - Reduce tumor growth
 - Lower your risk of cancer
 - Reduce your risk of multiple sclerosis
 - Lower your risk of diabetes
- New studies continue to highlight vitamin D benefits

Study identifies vitamin D's benefits for diabetic heart health

Nutra Ingredients.com; Stephen Daniells, 24-Aug-2009

Is there a health problem?

Low consumption of vitamin D is a concern

Breaking News on Supplements & Nutrition - North America

**Be aware of vitamin D insufficiency, says
US Dermatology Academy**

By Lorraine Heller, 16-Jul-2009

***This situation creates the opportunity
to increase consumption of mushrooms
Worldwide***

Mushrooms as a Source of Vitamin D

- **Mushrooms are the only non-animal food that can provide Vitamin D**
 - Cultivated mushrooms unexposed to UV light do not provide vitamin D
 - Mushrooms have relatively high levels of ergosterol - when exposed to UV light is converted to ergocalciferol (known as vitamin D₂)
- **A study performed by the United States Department of Agriculture demonstrated how continuous UV exposure can accelerate vitamin D in mushrooms – achieving levels > 100% DV in **8 minutes** of exposure time.**
- **A study performed by The Pennsylvania State University, using pulsed UV light, demonstrated that vitamin D can be increased >100% DV in **under 1 second**.**

Products on the market

Monterey Mushrooms touts vitamin D benefits

Published on 01/07/2009 (The Packer)

“We’re challenging people to get more vitamin D and get their levels up,” said vice president of biotech and product development John Kidder.



Products on the market

Dole Mushrooms pack a vitamin D boost

Published on 05/28/2008 (The Packer)

“To boost the natural value of vitamin D in the mushrooms, the company exposes them to an intense burst of light similar to that of a camera flash for less than a second, said Gary Schroeder, director of Dole Mushrooms and president of Oakshire Mushroom Farm Inc., Kennett Square, Pa., which supplies Dole-brand mushrooms.”



Can Vitamin D Mushrooms Create Consumer Interest?



Consider what Good Housekeeping magazine has to say!

First Annual VIP (Very Innovative Products) Awards

Thousands of products are reviewed in GHRI's labs each year. Many are problem-solving. Many perform well. And quite a few are innovative. But the winners of GH's First Annual VIP (Very Innovative Products) Awards meet *all three criteria*.

Portobello Mushrooms

Most of us don't get enough vitamin D — a real concern, because low levels are linked to cancer, heart disease, high blood pressure, and diabetes. What's more, very few foods provide much of the nutrient. Enter Dole's Portobello mushroom caps and slices: One package contains 800 IUs of D, the daily amount experts suggest. The secret is a simple flash of light during the growth process, which helps the mushrooms synthesize more D, without changing the taste. *\$3.50 for six ounces, Dole; major supermarkets*

How did the mushroom industry get to this point?

There has been a growing number of research studies investigating how ultraviolet treatment of fresh mushrooms increases vitamin D2

Light-zapped mushrooms filled with vitamin D

Bringing 'shrooms out of the dark packs them with sunshine nutrient

Ap Associated Press

Tues., April 18, 2006



Research Studies – Mushroom + UV Exposure = Vitamin D

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- Jasinghe, V. J., Perera, C. O. (2005). Distribution of ergosterol in different tissues of mushrooms and its effect on the conversion of ergosterol to vitamin D₂ in edible mushrooms. *Food Chem.* 92, 541-546.
- Jasinghe, V. J., Perera, C. O. (2006). Ultraviolet irradiation: The generator of Vitamin D₂ in edible mushrooms, *Food Chemistry*, 95, 638-643
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- Roberts, J. S., Teichert, A., McHugh, T. H.. (2008). *Journal of Agriculture and Food Science, Vitamin D₂ Formation From Post-Harvest UV-B Treatment of Mushrooms (Agaricus bisporus) and Retention During Storage*
- Beelman, R. (2008). Mushroom Short Course; *Mushroom Nutritional Research*; Dr. Robert Beelman Professor of Food Science, The Pennsylvania State University
- Beelman, R.B. and Kalaras, M.D. (2008). Vitamin D₂ Enrichment In Fresh Mushrooms Using Pulsed UV Light
- Williams, R. (2009). Installing a Vitamin D System for Pulsed Light Treatment of Mushrooms; Xenon Corporation
- Koyyalamudi, S. R.; Jeong, S. C.; Song, K.Y.C., Pang, G (2009). Vitamin D₂ Formation and Bioavailability from *Agaricus bisporus* Button Mushrooms Treated with Ultraviolet Irradiation. *J. Agric. Food Chem.*, 57, 3351-3355

Focus of research

- What amount of vitamin D increase is achieved?
- Does the UV intensity influence the level of vitamin D?
- Is there a reduction in vitamin D during an 8-day shelf life?
- Does the color of the mushroom change?
- Is there any difference when mushrooms are washed or sliced?
- What is the added cost to treat mushrooms in a commercial installation?
- Is there a temperature rise during exposure?
- Can different types of mushrooms be treated?
- Is there any difference in vitamin D levels for different mushrooms?

UV Delivery Methods

- Initial studies done with mercury UV-B lamps
- Increasing number of studies being done with xenon pulsed UV light lamps
 - **Penn State -USA (studies in 2008 and 2009)**
 - **Xenon Corp (study in 2008)**
 - **Mushroom Growers (2008 – 2009)**
 - **Australian Mushroom Growers Association (2009)**

Pulsed UV Light Treatment of Mushrooms at Xenon Corp



System: RC-742 with 16" lamp housing and Steri Chamber														RDI =		400		% of your daily requirement	% of your daily requirement per mushroom
By: R.Williams														IU of Vitamin D					
Weight Lbs	Temperature of Deg F	Inches Diameter of Mushroom	Orientation	Electrical Energy / pulse	Number of pulses	Distance inches	Lamp Type	BB Energy read / pulse	BB Energy Integrated	Act - 5 Sed 240 Read / pulse	Act - 5 Sed 240 Integrated	IJ / 100g / pulse	IJ/100g / control Portobello	IJ / 100g / pulse B VS C	IJ / 100g / pulse D /mushroom				
0.341	78	5.03	Top Up	505 Joules	1	1.25"	C	1.12	1.12	0.0319	0.0319	184	184	9.2	1.511	284.6	71.2%	71.2%	
0.319	79	5.26	Top Up	505 Joules	2	1.25"	C	1.12	2.24	0.0319	0.0638	383	391.5	19.15	1.452	554.2	138.0%	138.0%	
0.269	79	4.85	Top Up	505 Joules	3	1.25"	C	1.12	3.36	0.0319	0.0957	374	325	18.7	2.230	456.3	114.1%	114.1%	
0.286	78	4.79	Top Up	505 Joules	2	1.25"	B	0.873	1.746	0.0343	0.0686	556	278	27.8	1.000	721.3	180.3%	180.3%	
0.335	79	4.9	N/A	N/A	0	N/A	N/A	0	0	0	0	20	N/A	1		30.4	7.6%	7.6%	
Weight Lbs	Temperature of Deg F	Inches Diameter of Mushroom	Orientation	Electrical Energy / pulse	Number of pulses	Distance inches	Lamp Type	BB Energy read / pulse	BB Energy Integrated	Act - 5 Sed 240 Read / pulse	Act - 5 Sed 240 Integrated	IJ / 100g / pulse	IJ/100g / control Portobello	IJ / 100g / pulse B VS C	IJ / 100g / pulse D /mushroom				
0.24	71	2.2	Top Up	505 Joules	1	1.25"	C	1.12	1.12	0.0319	0.0319	674	674	33.7	1.0460	733.7	183.4%	45.9%	
0.278	70	2.3	Top Up	505 Joules	2	1.25"	C	1.12	2.24	0.0319	0.0638	1670	835	83.5	0.8443	2105.8	526.9%	131.6%	
0.268	71	2.17	Top Up	505 Joules	3	1.25"	C	1.12	3.36	0.0319	0.0957	1770	590	88.5	1.1949	2151.6	537.9%	134.5%	
0.241	71	2.12	Top Up	505 Joules	2	1.25"	B	0.873	1.746	0.0343	0.0686	1410	705	70.5	1.0000	1541.3	385.3%	96.3%	
0.228	70	2.11	N/A	N/A	0	N/A	N/A	0	0	0	0	20	N/A	1		20.7	5.2%	1.3%	
mushroom to window of housing.																			
Stan Labs																			
h part number 890-1958																			
msh part number 890-1957																			
w for each sample																			



Study on Portobello and White Mushrooms using Pulsed Light

Results from tests performed at Xenon Corp's lab in Wilmington, MA

No Exposure - control	IU	% DV
<i>Portabella control</i>	30	8%
<i>Sliced White Whole control</i>	20	5%
Portabella		
<i>1-pulse</i>	285	71%
<i>2-pulses</i>	554	139%
<i>3-pulses</i>	456	114%
Sliced White Whole		
<i>1-pulse</i>	734	183%
<i>2-pulses</i>	2106	526%
<i>3-pulses</i>	2151	538%

As few as 2-pulses, applied in less than 1-second produced vitamin D >100% DV in fresh mushrooms

Study on White Button, Brown Button, Shiitake and Oyster Mushrooms

Results from tests performed at Penn State, Dept of Food Science

%Daily Value* Vitamin D ₂ In One Serving (84g)					
MUSHROOM TYPE	Number of Pulses				
	0	1	2	3	4
White Button (<i>Agaricus bisporus</i>)	0%	325%	562%	724%	824%
Brown Button (<i>Agaricus bisporus</i>)	4%	362%	522%	746%	899%
Shiitake (<i>Lentinula edodes</i>)	3%	490%	867%	1200%	
Oyster (<i>Pleurotus ostreatus</i>)	15%	651%	1129%	1618%	

Notes

1 - *100% Daily Value (DV) = 400 IU

2 - Pulse rate = 3 pulses/second; Xenon Corp "B" Lamp; 505 Joules/pulse

3 - Mushroom top placed 1.25" below quartz window, 16" Lamp Housing

4 - Study performed by M. Kalaras and R. Beelman, Dept of Food Science, Penn State University

1-pulse, applied in under 1-sec increased vitamin D₂ to over 100% DV in one serving fresh mushrooms

Pulsed UV Light Equipment

Lamp Housing with Flashlamp



Controller



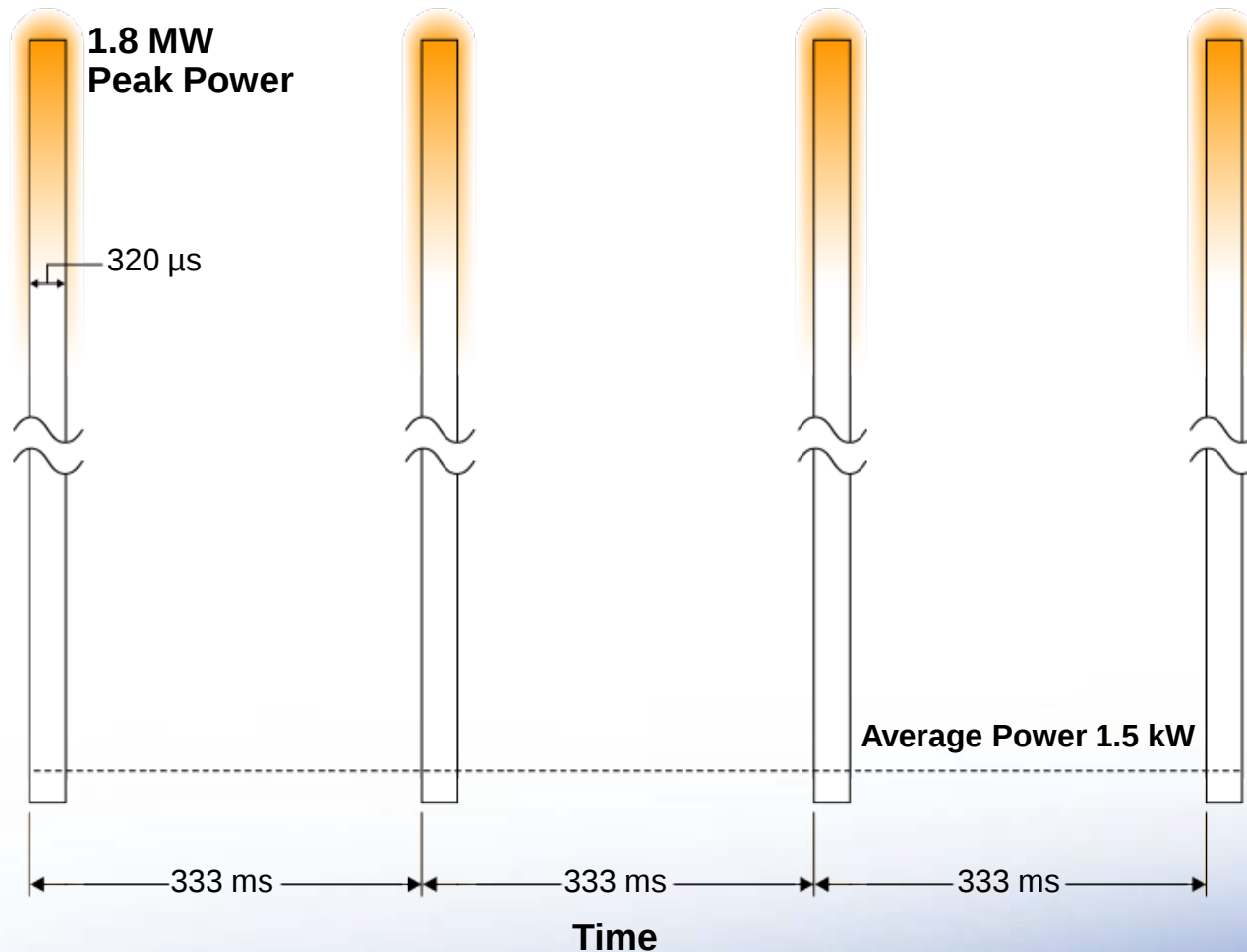
Lamp Housing Blower



The Basics of Pulsed Light

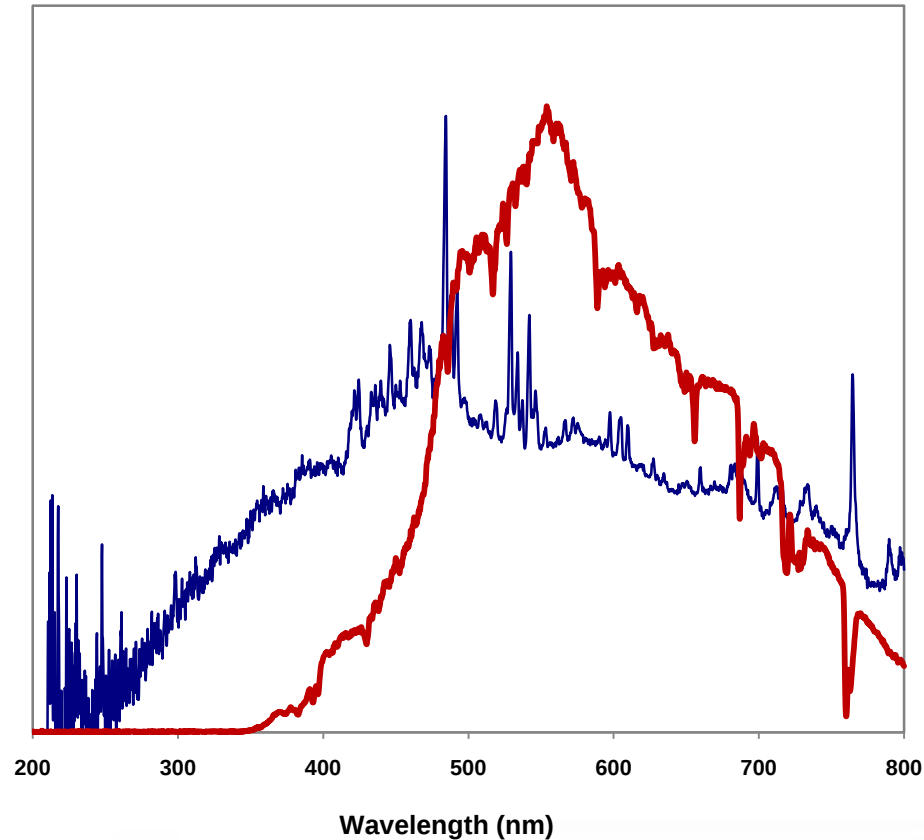
High Peak Power Low Average Power

Peak vs. Average Power



Spectra

– Sunlight vs. Pulsed Light Lamp

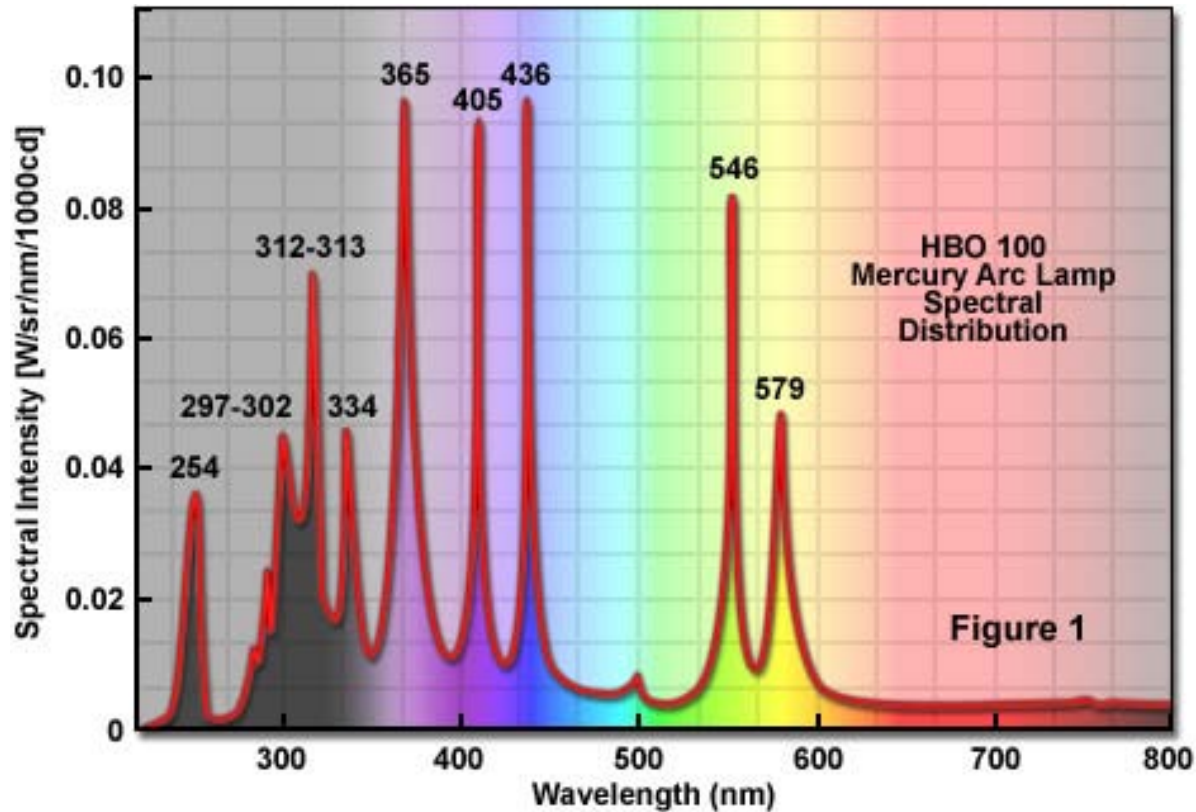


Blue = xenon *Pulsed Light lamp* **Red** = *Sunlight*

Pulsed light more closely matches the spectrum of natural sunlight

UV-B (Mercury) Lamp

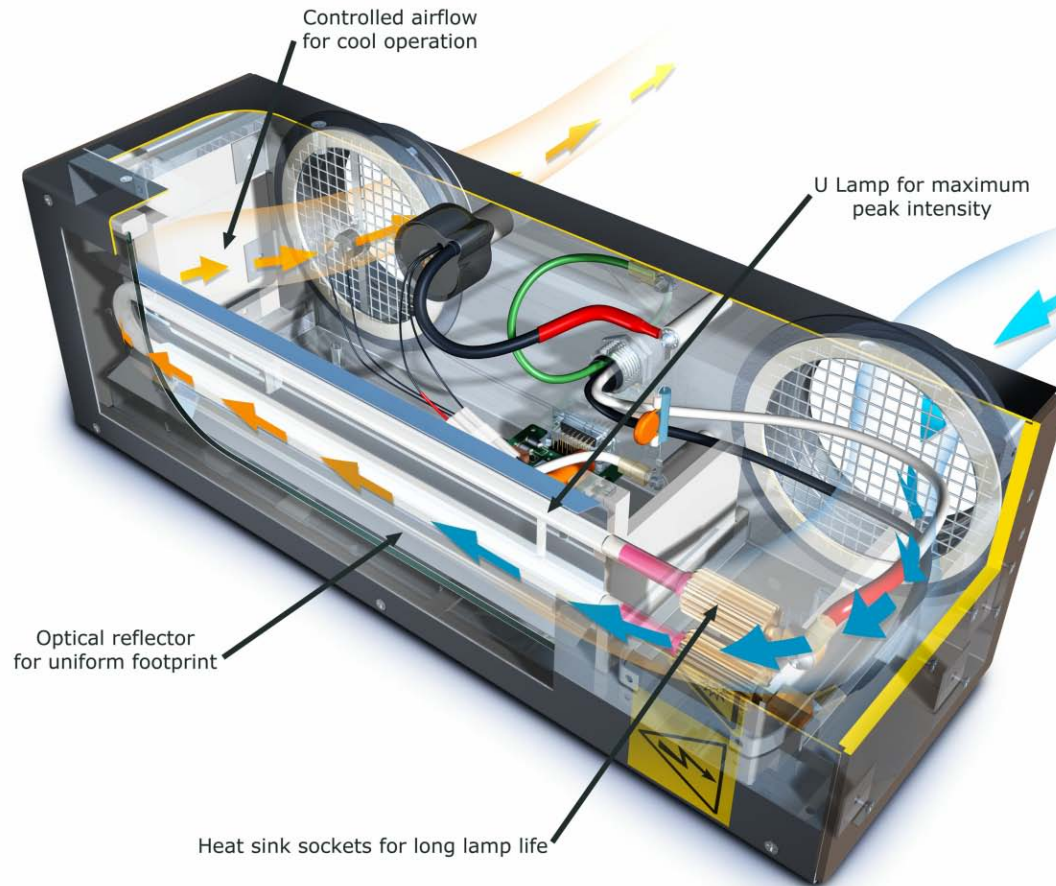
- 'line' spectra



Zeiss-Campus, Fundamentals of Mercury Arc Lamps

Mercury Arc Lamp Spectra is not continuous like the Sun spectra

The Heart of a Pulsed Light System



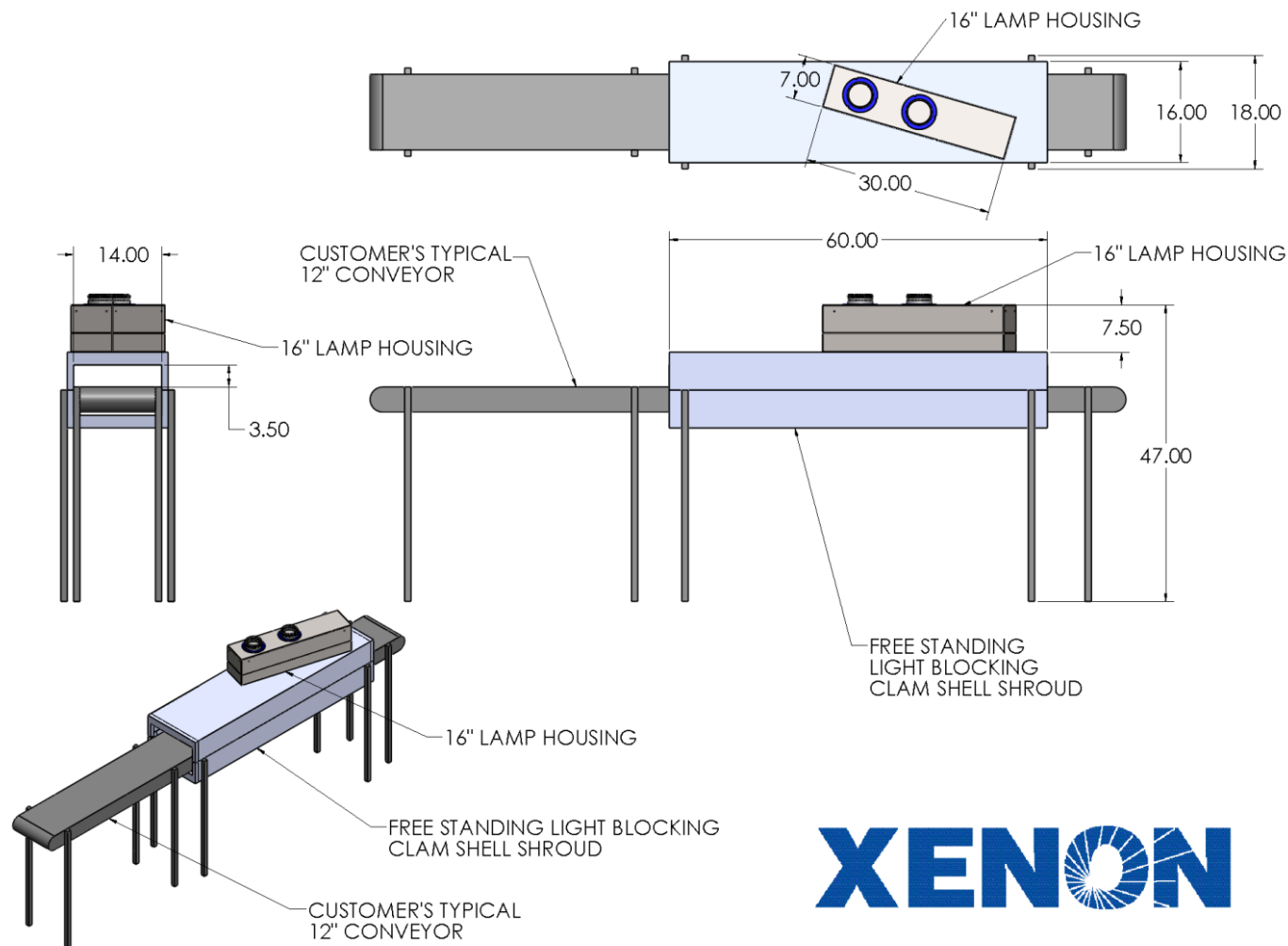
Integrating Pulsed Light into an Inline Processing system

- **Step 1** – Review installation guidelines¹ with Xenon
- **Step 2** – Design a light blocking tunnel to fit over mushroom conveyor belt
 - Pulsed light is very bright – must be shielded from operator eyes
 - We can recommend experienced integrator to help but have found most growers can do this work
- **Step 3** – Confirm actual vitamin D level
- **Step 4** – Establish routine verification and maintenance schedules

¹ Williams, R. (2009). Installing a Vitamin D System for Pulsed Light Treatment of Mushrooms; Xenon Corporation



Designing Light Blocking Tunnel Over Conveyor Belt



XENON

Variables that control the level of vitamin D delivered

- Variety of mushroom
 - oyster, portabella, white button, shiitake...
- Mushroom size
- Position below lamp housing window
- Position of lamp housing over conveyor
- Speed of conveyor belt



Designing a system using Pulsed UV Light system, can address all variables and result in a reliable, repeatable, inline process at grower facilities.

Pulsed UV Lamp vs. Mercury Lamp – for vitamin D enhancement

	Pulsed Light System	Mercury Lamp System
Spectra	Close to Sunlight	Line Spectra
Heat	Minimal IR	Significant IR
Personnel Safety	Risk Eliminated	Mercury (Hg)
Environmentally Friendly	No Hg & Less Energy	Hg and More Energy

Future Advances

Longer lamps

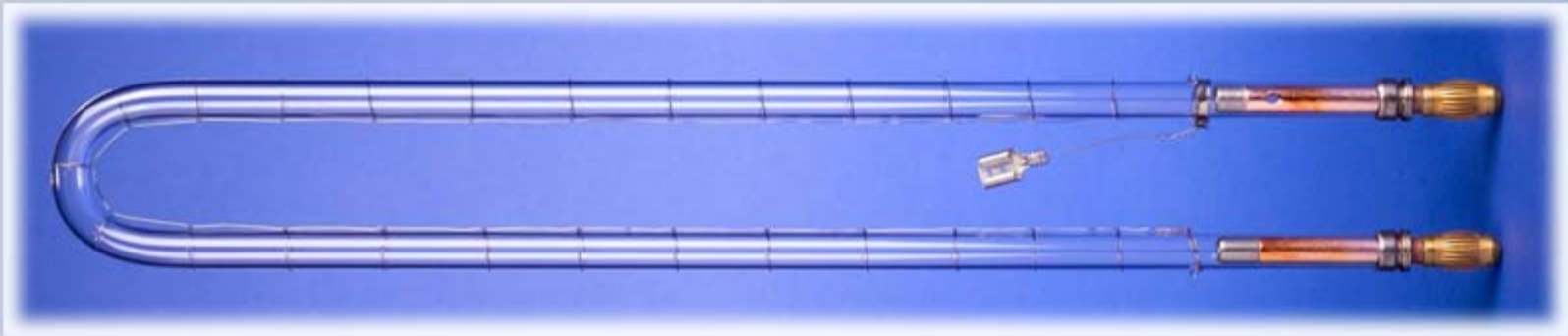
Increase the optical footprint
16-inch lamp > 30-inch lamp > ?



Future Advances

New Lamps and Optical Designs

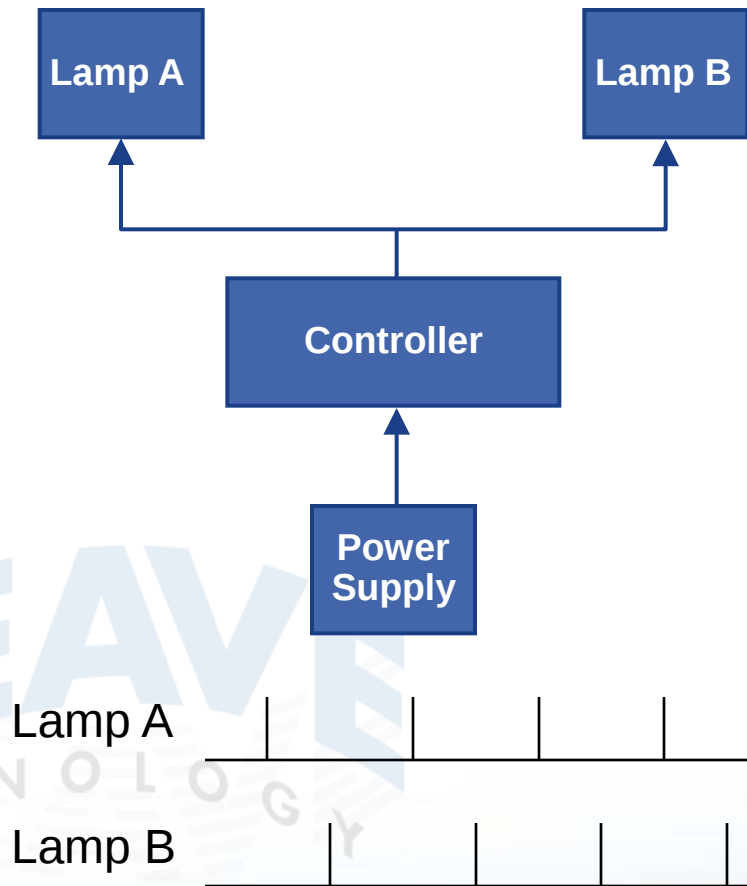
U-lamp widens
the optical footprint



Future Advances

InterWeave™ Technology

- Less hardware
 - Less cost
- Simplified controls
- Handle multiple conveyor lines
- Increased mushroom output



Acknowledgements

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- Dr. Robert Beelman - Penn State University
- Laura Phelps - American Mushroom Institute
- Bart Minor - American Mushroom Council
- Jack Cook - American Mushroom Cooperative
- Australian Mushroom Growers of Australia
- Mushroom Growers Worldwide
 - USA
 - Canada
 - South America
 - Mexico
 - Ireland



Questions & Comments

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